SYSTEMS METHODS AND THEIR APPLICABILITY TO ACCIDENT COSTING

Thesis

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SYSTEMS METHODS AND THEIR APPLICABILITY TO ACCIDENT COSTING

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Abstract

This thesis concerns the subject and problem of accident costing, and an examination of the value and applicability of a holistic, systems approach to such issues.

The initial impetus for the study arose through discussions between members of the Open University Systems Group and the Electricity Council Safety Branch. In considering particular classes of accidents that occur in the Electricity Supply Industry, it was realised that the Industry had no idea of the scale of monetary costs involved, and no mechanism for evaluating them. Thus the need to devise a costing framework was identified.

To meet the Industry's need the problem was treated as a straightforward costing exercise. Following a study of the literature on valuing life and costing accidents (detailed in Section 1), and a period of field research at two Electricity Supply Industry Area Board districts, a costing framework, or model, was developed of areas of potential post factum costs for the Industry as a result of an accident (Section II). From the model, costs to the Industry both direct and indirect, were calculated, thereby illustrating areas of actual and potential high cost. Using the Industry's analysis of accidents in terms of 'causation', the

class of accidents of major concern is that to which 'Electricity' is stated as being causal. Although these accidents only form between four to seven percent of the total annually, their significance lies in the high proportion resulting in serious injuries and high costs.

The method adopted provided the Electricity Supply Industry with a costing model, but was restricted by this desired result. Such a relatively narrow reductionist approach tends to rely on limiting assumptions and to ignore wider issues. In Section III of the thesis, therefore, the problem is reexamined using two different systems methodologies in preliminary stages. Firstly, the Checkland methodology, a 'soft' systems methodology and secondly the de Neufville and Stafford methodology, a 'harder' methodology. These methods lead to different conclusions and wider implications for implementation strategies. However, both the Hard and Soft Systems methodology used tended to broaden the understanding of some aspects of the problem whilst constraining others. Thus, the author of the thesis, together with two other members of the Systems Group developed the Hard Systems method in an attempt to bridge an apparent methodological gap. This method and other conclusions are to be found in the final (fourth) section.

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Chapter One. Introduction.

1.1. History of the Thesis

This thesis is largely the result of work carried out for the Electricity Council to determine a framework for costing accidents within the Electricity Supply Industry.
The impetus for the initial research came from earlier work carried out between the Open University Systems Group and the Electricity Council Safety Branch. (Hooper 1976).
Location of the work within the context of systems acknowledges the value of a holistic approach and the potential complexity of what might originally appear to be a straight forward problem.
Systems practice can be seen as a learning process in two ways: learning about the problem situation, and learning about the strenghts and weaknesses of existing systems ideas and the difficulties in applying them. Similarly, this thesis is an interaction between the application and the ideas: an attempt to increase the body of applied systems work, simultaneously testing the impact of some existing systems theory.
The systems movement, which can be described as a loose federation of people working in different disciplines applying systems ideas to their own particular fields, is still a new area. The last thirty or so years have seen

the development of the subject as attempts have been made to break down the boundaries erected between disciplines by using the approach. However, much work carried out to 'legitimate' systems has been concerned with formulating basic systems concepts, models, techniques and methodologies; the body of applied systems work is still small. The need for a more holistic and appropriate approach to practical problems initiated the impetus to reject traditional scientific reductionism, and thus the application of systems ideas is a vitally important area for the development of the subject of systems as a whole.

1. 2. The Problem

The problem was originally outlined in a project brief which is to be found in Appendix 1 of this thesis. The need for a system to derive the costs of accidents was first identified in the course of the following process: In the regular compilation of accident statistics the Electricity Council Safety Branch had recognised particular classes of accidents as being of especial interest on account of their potential, and frequently actual, severity in terms of human injury and damage to equipment. It was felt that such incidents should be further investigated, to determine ways of reducing the associated hazards, even though they were not always statistically significant.

However, in order to evaluate the scale of resources appropriate to be allocated to this function the Safety Branch wished to determine the annual cost of incidents in this category to the Industry. At this time no procedure existed under the Industry's accident information retrieval system to determine accident costs of either, specific categories or annual totals. Thus the identification of factors to be routinely collected for any accident in order to derive costs was recognised as an important research area.

1. 3. Map of the Thesis.

The thesis is divided into four sections, prefaced by the introduction and closed by a concluding section. Section I contains a review of the body of work that has been written on costing accidents and life valuation. Although, as can be seen, a substantial amount of literature exists, significant problems are to be found with most of the methods employed, and only little use was made of them in the actual costing carried out in Section II.

In Section II the approach used and the costing model developed to determine accident costs for the Electricity Supply Industry are explained and described, together with the use made of available data to derive results. The last chapter in

Section II describes the problems encountered with such a costing and the need to approach the subject from a more holistic viewpoint.

In Section III the accident costing problem is explored by application of two different systems methodologies, firstly that of Checkland and secondly that of de Neufville and Stafford. Very different results were to be found from applying these methodologies, as compared with the economic approach used in Section II. In Section III the bulk of the work was concerned to question the specific remit, and the costing model would have been only a part of a package presented to the Industry to improve safety and elevate the status of the Safety Branch.

The concluding section, Section IV, contains a discussion of the Hard Systems method which the author developed with two other members of the Open University Systems Group as a direct result of this work and the difficulties experienced using existing methodologies in other socio-technical organisational contexts. In the final chapter of Section IV, general conclusions are made about the nature of the exercise of costing accidents and the safety function in the Electricity Supply Industry.

SECTION I

A review of the main approaches to valuing life and costing accidents.

Chapter Two

Introduction and Examples of Existing Estimates of Accident Costs.

2. 1 Introduction.

Most recent literature on costing accidents and the value of life has concentrated on the subject from a subjective viewpoint, in attempting to attach a price to lost lives and the suffering and other disbenefits incurred by the individual, his family and society as a whole.
Much of this body of work is not directly relevant to the scope of the Electricity Council Project; the Council needed information about the more directly material and financial costs that routinely result for the industry when accidents occur. However, even in discussion of such an apparently narrow classification of costs the more subjective aspects should not be ignored, for they represent a substantial levy for the rest of society, or parts of society. The debate about how and what should be valued is significant in revealing the confusion and dissension which characterises the subject; it is a debate unlikely to be resolved because of its inherently political nature.

2. 2 Existing Estimates of Accident Costs.

Existing estimates of accident costs and the methods employed vary according to the purpose to which they are put. The work of Beckingsale (1963), Reynolds (1956) and Dawson (1967 and 1971), concentrates largely on the more readily quantifiable direct costs of accidents. (Although Dawson does consider the subjective costs imposed by (road) accidents and attaches a figure of £5,270 per fatality in his 1971 paper).

In Reynolds' view it is beyond the competence of economists to assign objective values to the losses suffered in terms of pain, fear and suffering as a result of accidents although these are considered to be of great importance. Therefore only the more concrete and ascertainable burdens in the form of net loss of output of goods and services due to death and injury and the expenditure of resources necessary to make good the effects of accidents are considered. These he breaks down into the following categories:-

a) damage to property

b) medical costs

c) administrative costs

d) net reduction in national output

Reynold's 1956 estimates of the average cost per casualty are:- death: £2,000; serious injury: £520; slight injury: £40.

Dawson (1971) uses similar cost categories as Reynolds with the inclusion of rather arbitrary avarage values for the subjective cost of casualties, (of: £5,000 for fatalities; £200 for serious injury and £10 for slight injury). The estimates Dawson derives are:- death: £16,920; serious injury: £1,130; slight injury: £203.

Figure 1 overpage illustrates the variabilities and problems involved in values of accident costs. The table is taken from Sinclair's Appendix to the Roben's report (1972). It purports to show variabilities introduced by the variations in the practice of categorising costs, however, there is little indication of the methods and categories used to produce the different estimates. Furthermore, meaningful comparison of the costs is made more difficult as it is unclear whether or not all costs have been converted to 1972 (or any base year) prices.

Figure 1. ACCIDENT COSTS IN GREAT BRITAIN AND OVERSEAS.

Area Covered	Date	Average Cost of Accident						Type of Accident	Notes
France	1958	Stoppage accidents £1.80			Serious accidents with permanent partial impairment of functions. £2,580.00			Total Industrial	
Great Britain	1963	Non-lost time			Lost time (over 3 days)			Total Industrial	
		£1·38			£188				
Great Britain	1968	Serious						Coal Mining	No definition of serious injury given. Minor injuries costed as loss of output at £2 per ton.
		£5,000							
Germany	1965	Slight	Less than 11 days	Less than 21 days	Less than 45 days	45 days & over temporary disability	45 days & over permanent disability	Leather Industry.	
		D.M 7·45	D.M 120·60	D.M 324·00	D.M 877·00	D.M 1,620,00	D.M 116,800·00		
Great Britain	1963	Slight				Serious		Road	Subjective cost of serious accident £230
		£150				£710			

(Source: T. Craig Sinclair).

Chapter Three

Approaches to Life Valuation.

The main approaches to life valuation include the following approaches:-

1) The Legal Compensation method.
2) The Personal Insurance method.
3) The Discounted Future Earnings approach.
4) The Willingness to Pay method, which includes:
    a) Models based on self-evaluation and direct observation of limited specific choices in the cost analyses.

    and b) Labour Market analyses based on revealed preferences.

3. 1 The Legal Compensation Method.

Compensation awarded to individuals and/or their families for injuries or death can be used as an indicator of the value that society places on human life.
Figure 2 overleaf gives examples of a range of damages awarded by the courts for fatalities and near fatalities which can be seen as a reflection of the value a subsection of society places on loss of life and the curtailment of the normal enjoyment of life.

SEX	AGE	FAMILY	OCCUPATION	FATALITY YES/NO	CIRCUMSTANCES	DAMAGES
M	52	Married	School Caretaker	YES	Gas explosion in Classroom.	£23,500
F	42	Mother of 4	Housewife	NO	Mistake during steril-isation operation.	£59,760
F		Married	Housewife	YES	Basle Air Crash.	£11,700
F		Married	Housewife	NO	Mistake during steril-isation operation.	£53,249
M	3	-	-	NO	Wrong injection.	£31,318
M	53	Married	Production Manager	NO	Anaesthetist's negligence.	£112,187
F	41	-	Psychiatrist	NO	Anaesthetist's error	£243,309
M	49	Father of 3	Woodwork Machinist	YES	Car accident.	£20,522

Fig.2. Recent (1977-8) damages awarded for fatalities or near fatalities (U.K.)
Source: Unit 11 "Risk" The Open University.

Damages payable in cases where liability is proved covers not only pecuniary loss, anticipated loss of future earnings, but also such items as pain, suffering, loss of expectation of life and the impairment of social activities.

3. 2 Personal Insurance Method.

It can be argued that the amount an individual chooses to insure himself for to alleviate the consequences of injury or death can be used to estimate the value he places upon his life.

3. 3 The Discounted Future Earnings Approach.

Approaches to life-valuation based on expected future earnings include Dublin and Lotka (1946), Huebner (1927), Weisbrod (1961), Miller (1961), and Rice and Cooper (1967).

The value of a person is defined in terms of his economic worth as a productive member of society, and the amount varies according to age, sex, colour and degree of educational attainment.

The method presented by Rice and Cooper (1967) takes into account life expectancy for different age, sex, and colour groups, varying labour force participation rates, the current changing pattern of earnings at successive ages, imputed value of housewives services, and the discount

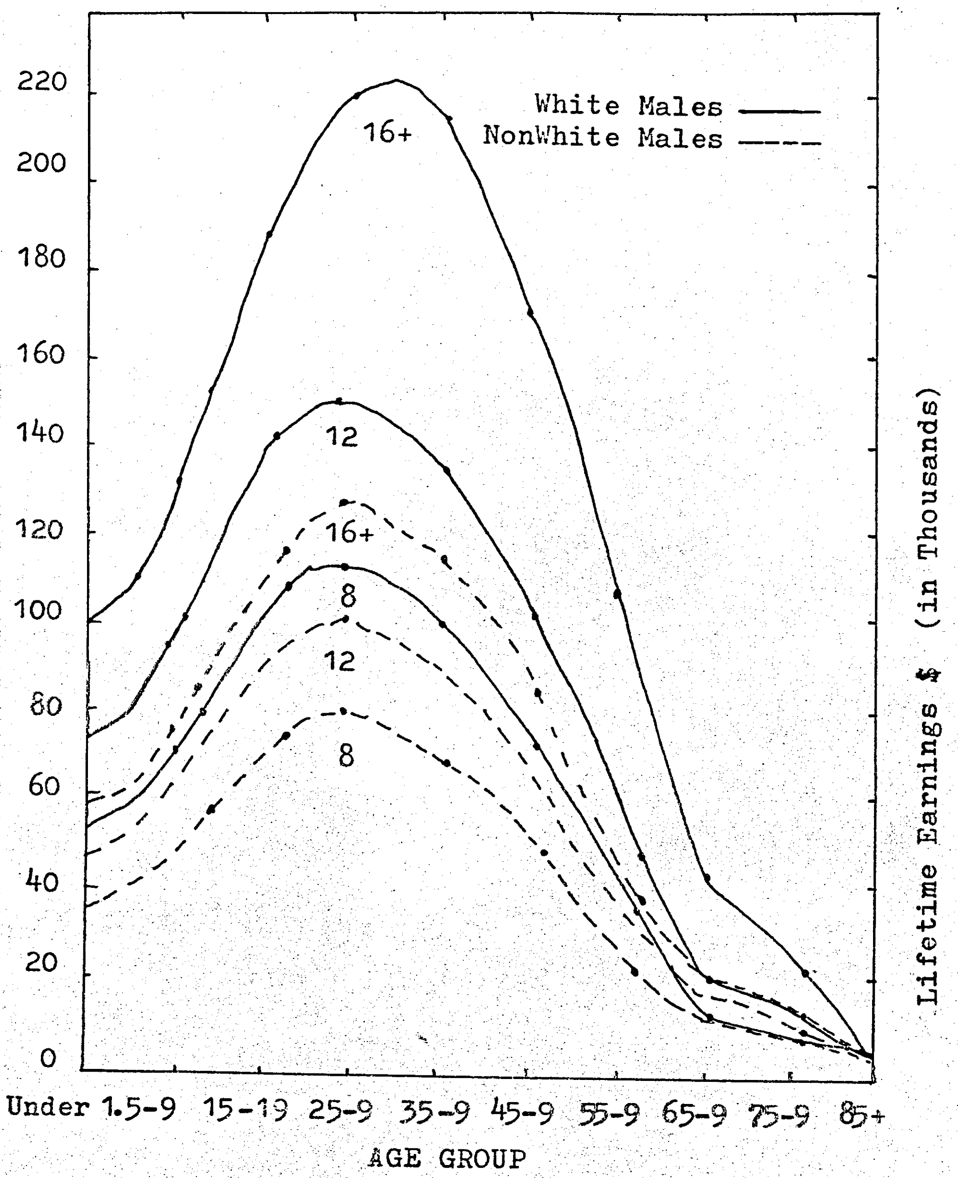


Figure 3. Present value of lifetime earnings of males by age, colour and years of school completed, discounted at 4 per cent, 1964.

Source: Rice and Cooper (1967).

rate. As stated by Banks and Kotz " a given sum is normally worth more today than an equal sum at some future date" and thus discounting is employed to determine the present value of future earnings.

In their 1967 paper Rice and Cooper make use of a 4% discount rate. Their findings include the following:-

For males, the value of discounted lifetime earnings ranges from about $ 59,000 for infants to a peak of approximately $131,000 at ages of 25 to 29, and decreases to $750 at age 85 and over.

For females the discounted earnings range from about $36,000 for infants, to nearly $72,000 at ages 20 to 24, and down to $1,200 at ages 85 and over.

Figures 3 and 4 are illustrative of the comparative life valuations derived by Rice and Cooper using this approach. Figure 3 displays differing valuations according to age, colour and years of school education for males. Figure 4 shows similar information for females.

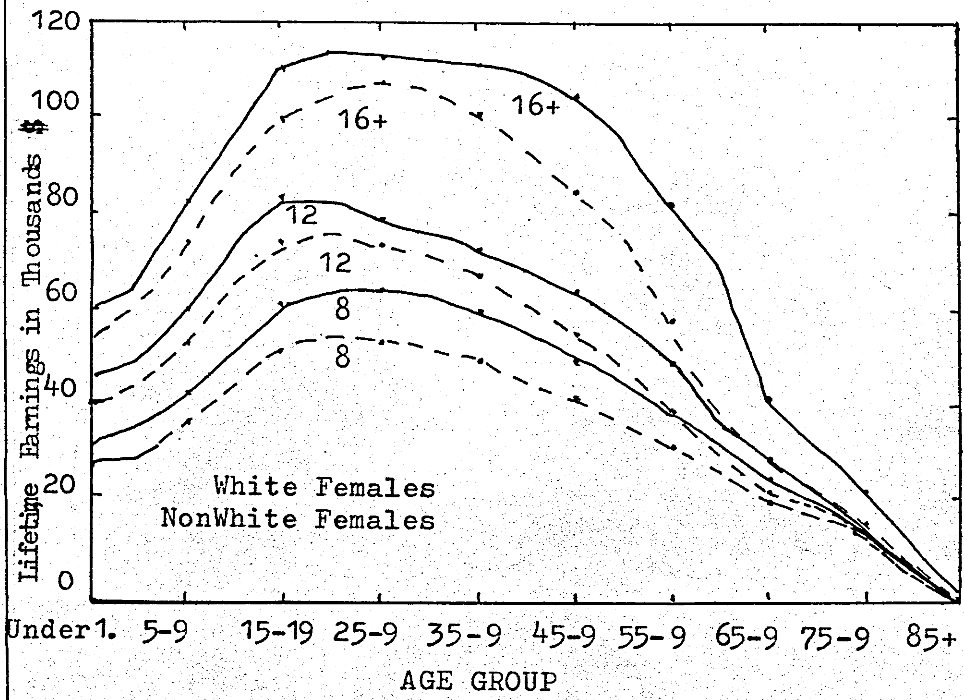


Figure 4. Present value of lifetime earnings of females by age, colour and years of school completed, discounted at 4 per cent, 1964.

Source: Rice and Cooper (1967).

3. 4 The Willingness to Pay Method.

a) Models based on self-evaluation and direct observation of limited specific choices.

Proponents of the diverse variations of this approach include Schelling (1968), Melinek (1974), and Jones-Lee (1976).

Schelling uses a direct inquiry approach to identify the value that can be placed on life-saving.

His principal matter of concern is with statistical rather than identified lives:

> "It is not the worth of human life that I shall discuss, but of 'life-saving', of preventing death. And it is not a particular death but a statistical death. What is it worth to reduce the probability of death - the statistical frequency of death - within some identifiable group of people none of whom expects to die except eventually?"

He introduces the 'consumer interest in reduced death':

> "...a program to save lives has been identified and we want to know its worth. The dimensions of the risks to be reduced are fairly well known, as it is the reduction to be achieved. Suppose also that this risk is small to begin with, not a source of anxiety or guilt. Surely it is sensible to ask the question: what is it

worth to the people who stand to benefit from it?".

Melinek's purpose is to derive a poulation average of the value placed by individuals upon their own lives.
In his 1974 paper the value placed upon life is defined by Melinek as:

> "the benefit derived at the cost of accepting a given incremental risk of death divided by the increment in the risk of death."

He uses a direct observation approach and gives examples of alternative possible estimation procedures - for example:

i) He observes the use of pedestrian subways to discover the critical time-saving that will induce individuals to cross a road directly rather than use a safer, but slower, subway crossing. The time differential is taken to reflect the minimum benefit that would just induce people to accept the extra risk due to crossing the road.
The value of life is calculated form this as follows:

$$Va \text{ (value of life)} = \frac{vtc}{Pa\,Pd}$$

Where tc is the critical time differential, v is the marginal value of time, Pd is the probability of an accident being fatal, and Pa is the probability of having an accident while crossing the road.

Using Road Research Laboratory data Melinek estimated Va by this method:

$$Va = £87{,}000$$

And ii) Melinek uses employment choices to elicit a value of life from the wage premia for risky occupation. Using Central Statistical Office data on industrial accidents and International Labour Office data on evaluation, the value of life Vc is estimated to be :

$$Vc = £200{,}000$$

Jones-Lee uses an interview/questionaire technique in conjunction with cost-benefit analysis to assess individuals' willingness to pay for marginal changes in risk of his own death or the death of anyone he cares about.

"An anticipated reduction in the morality rate during some period of time affords any individual three major components of value:

i) a reduction in his share of the real resource costs occasioned by the death of others.

ii) a reduction in his share of the loss of net output owing to the death of others.

iii) a reduction in the risk of his own death or the death of anyone he cares about.

If value is given the interpretation as an equivalent variation in income or wealth (i.e. as the sum that an individ-

ual would require to compensate for failure to make an allocative adjustment) then the marginal value of a change in risk is precisely the same as that given by the compensating variation definition of value. The appropriate value to place upon the anticipated saving of one (anonymous) life during a particular time period is (in addition to avoidance of real resource costs and losses of net output) given by the average, over the relevant population, of the marginal value in a decrease in risk. In so far as the concept of a 'value of life' has any relevance in the analysis of safety improvement this is the appropriate interpretation of such a concept. And empirical evidence suggests that the average 'marginal value of decrease in risk' for risk changes effective over relatively short periods of time has an order of magnitude in excess of £3m.
(Jones-Lee 1976.)

b) Labour Market Analysis based on revealed preferences.

Proponents of the labour-market analysis approach to valuing life include Smith (1976), Thaler and Rosen (1976), and Viscusi (1978).

Viscusi (1978) looks at data on 496 full-time blue-collar workers in the University of Michigan's 1969-70 "Survey of Working Conditions" to obtain estimates of the values that individuals implicitly attached to death and injury through their employment decisions. His major contribution to the debate is the inclusion of estimates for losses associated with non-fatal injuries. Viscusi feels that investigations directed at obtaining an 'elusive value of life' are largely misdirected and that the direction should be towards determining schedules of the life and health status for the entire population.

Viscusi determines market prices in the context of potentially hazardous employment. Job hazard indices for each workers' jobs are constructed. The workers' earnings are then regressed on his/her job hazard indices, his/her personal characteristics, and the job characteristics in order to obtain the implicit monetary price workers receive for risks of death and injury. The results of this analysis were then used by Viscusi to estimate the dollar values that individuals attach to the loss of life and to a work injury. These health outcomes were evaluated at roughly $\$10^6$ and $\$10^4$ respectively.

Chapter Four

A Cost Effectiveness Approach to Safety.

This approach, as put forward by T. Craig Sinclair (1972), embodies the idea that accident prevention methods should be related to their efficiency in reducing accident costs

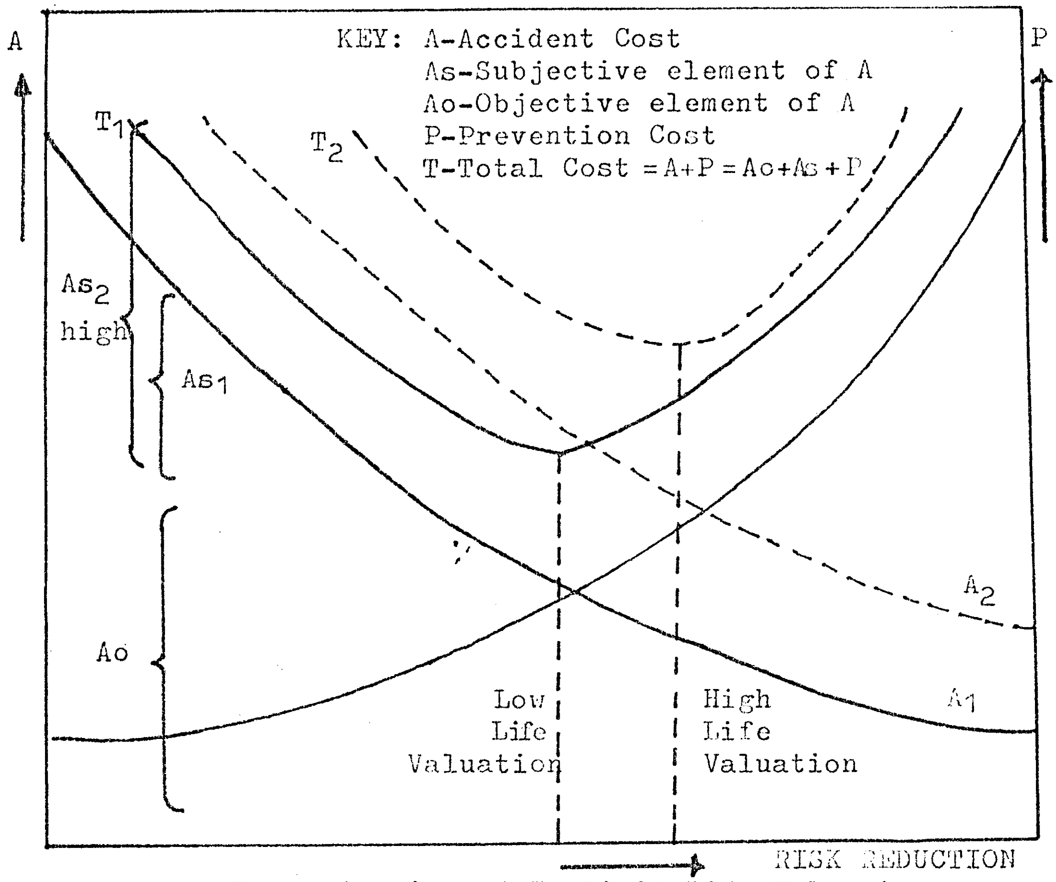


Figure 5. Determination of Implicit Life Valuation.
(Source: T. Craig Sinclair) 1972.

both human and material. The author uses the above figure to illustrate that within certain limits the minimum total cost point lies close to the cross - over point of the accident and prevention curves; and thus for the majority of cases where the whole curve cannot be derived annual prevention expenditure is equated to annual cost and a life valuation is dtermined from this; Annual prevention cost equals annual accident cost which is equal to the annual average risk multiplied by the value of life at risk.

To apply this method it is essential for the items of expenditure constituting prevention costs to be agreed.

Using data from Agriculture Craig-Sinclair derives an implicit life valuation of £10,863. (As shown in Figure 6 Overleaf)

Figure 6.

Prevention expenditure per head

$$(PH)\ 1 = \frac{\text{deaths}}{\text{risk population}} \times (\text{subjective cost} + \text{objective cost})$$

$$+ \frac{\text{serious injury}}{\text{risk population}} \times (\text{subjective cost} + \text{objective cost})$$

$$+ \frac{\text{other injuries}}{\text{risk population}} \times (\text{subjective cost} + \text{objective cost})$$

i.e. $PH = RD\ x(As + Ao) = Rs\ x(As = Ao) + Ro\ x(As + Ao)$

For simplicity the assumption was made that (As + Ao) is zero for risks other than death risks, thus:-

$$PH = RD\ x(As + Ao)$$

And as objective losses in agriculture are small in comparison with other costs, for this evaluation the author has chosen to ignore them, thus:-

$$PH = RD \times L$$

(L)Life Valuation has been substituted for the subjective costs, and :-

$$L = \frac{PH}{RD}$$

The average death risk for 1966-68 was 0·197 per 1,000 workers; and annual prevention expenditure was £700,000 for 1967; and the population at risk was 327,000;

From the equation:-

$$PH = \frac{\text{prevention expenditure}}{\text{risk population}} = \frac{£700,000}{327,000} = £2{\cdot}14$$

and substituting in the equation:-

$PH = RD \times L$ we get:-

$$L = \frac{2{\cdot}14}{0{\cdot}197 \times 0{\cdot}001} = £10,863$$

i.e. the implicit <u>life valuation is £10,863</u>

Chapter 5.

Discussion of the Approaches to Costing Life and Injury.

As can be seen from the numerous but disparate methods summarised above and tabulated in Figure 7, there is agreement among economists and policy makers about the need to value life but no consensus about how it should be done.

The question of whether or not it is callous to engage in attempting to place values on human life seems to miss the point, for as it is obviously being done either overtly (as for example in court cases involving awards), or implicitly (as for example by those involved in public decision making who do not purport to value life or lives specifically when evaluating or deciding between certain policies), surely therefore it is more appropriate to discuss these issues openly and the questions that should be asked are who is making decisions about the worth of human life and what criteria they are applying.

Rhoads says :-

"...I am quite sure that we will never see the day when value of life issues are debated as freely and openly as other public policy issues. Moreover, I do not think we ever should see such a day...

It is demoralising when society collectively and publicly

Author	Date of Valuation	Valuation	Notes on Method/ Accident Type
Schelling	1968	£4,000,000	Willingness to Pay Approach
Jones-Lee	1969	£50,000	Willingness to Pay Approach
Dawson	1971	£5,270	Subjective Cost Attached to Road Accident Costs
Sinclair	1972	£10,863	Cost Effectiveness Approach: Implicit Life Valuation
Melinek	1974	£87,000 and £200,000	Willingness to Pay Approach. (Two Data Sources - see text: 3.4)
Kemp and Kemp	1977/ 1978	£23,500	Legal Compensation. School Gas Explosion
		£20,522	Legal Compensation. Car Accident

Figure 7. Comparitive Life Valuations.

places a value on life. It is especially so when a decision is made not to save an identifiable individual."
But this seems rather to be evading the issue, and probably says more for the inadequacy and inequity of the existing methods of life valuation.

The first two approaches (the legal compensation method and the life insurance method) descibed are highly inappropriate as ways of evolving a generalised value of life for a statistical individual.

The Legal Compensation Method.

In death the damages awarded to the next of kin are based on compensating the victim's family for their losses, and although in calculating the sum to be awarded the courts may take into account such things as loss of future earnings loss of pension rights and pain/suffering and the loss of amenities of life itself, there is obviously no sum which will actually compensate a person for his/her own death.
As the amounts awarded, using this method, depend on the victim's circumstances they must be of little use in making assumptions about the average value of life: Criag Sinclair (1972) quotes Ison in summing up the law of liability as saying:-
"Liability for negligence is a capricious and unsatifactory method of compensating the victims of injury and disease.
For the same reasons, it is thoroughly inefficient as a

method of social cost accounting."

Similar problems arise with transferring values from <u>life-insurance</u> into generalised life values in that the insurance values reflect the insured's concern for his/her dependents, and more importantly, his ability to pay, rather than the value which the insured places on his/her own life. And the sums awarded cannot restore a person to his/her original level of welfare.

As Viscusi states:-

"The primary difficulty is that life and health involve non-transferable commodities for which no insurance contract can provide replacements."

The two economic methods of life valuation which are seriously debated and actually used in Cost Benefit Analysis as aids to decision making are the '<u>Discounted Future Earnings</u>' and the '<u>Willingness-to-pay</u>' approaches. Both of these approaches seem to have fundamental limitations and very inequitable implications.

<u>The Discounted Future Earnings</u> method would obviously yield unacceptable guidelines for policy if used as a means of valuing the worth of lives. For example: as men on average earn more than women the discounted future earnings figures show mens' lives to be of far more value than womens'. Rice (1966), tries to balance this by valuing housewives' labour at the weekly wage-rate of domestic ser-

vants, but this is inadequate as not only does it not take account of the housewives' longer work-week but it also degrades both the position of women in the home and that of domestic servants.
The policy implications using this method for the elderly and other low-income groups are similarly unacceptable:- compare for example the 'value' of two disparate economic groups in the U.S.A. using Rice and Cooper's 1967 figures:
$ 136,121 for white males aged 25-29, and:-
$ 396 for non -white males aged over 85.
As Rhoads says:

> " The discounted future earnings method for evaluating lives has probably done as much as anything to convince others that cost-benefit economists are presumptuous and wedded to a crude materialism."

The 'Willingness-to-Pay' approach appears to be fraught with problems of credibility. The method rests on determining the prferences of consumers either by interviewing or by observation of decisions taken by individuals at risk. Most observation studies are analyses of individuals' employment choices, but these choices will say more about the constraints of the economic climate and the individuals' bargaining power in terms of skills, personal wealth and political muscle. Criticisms of the interview method lay in three areas: Respondents may engage in strategic behaviour, and for example:

"A persons' altruism may be much greater when he knows he will not be required to back up his statements with out of pocket contributions." (Viscusi.)

Secondly, respondents may interpret the questions differently from the author and may also not give consistent answers to the same question couched in different ways. The questions asked typically involve thinking about choices involving small probabilities which is notoriously difficult.

And thirdly, the poll sample sizes of some of the proponents of the approach are rather small. Actons' (1973) sample was only 36; and in Jones-Lee's (1976) study only 30 out of 90 people polled responded. Those who did respond may be a significantly different group to those who had chosen not to answer.

However the most serious criticism of the 'Willingness-to-Pay' method must be that it does not tell what it purports to, for in situations of being able to pay to avoid death and injury most people would pay as much as they were able, thus the 'Willingness-to-Pay' figure reveals more about absolute wealth than the value of life.

The valuations of life and limbs are used within the framework of cost benefit analysis - itself a dubious technique for social decision making. Cost Benefit Analysis consists of the enumeration and evaluation of a set of consequences of a particular change in the context of a much wider economic environment that remains essentially unaffected. Criticisms and problems associated with the application of Cost Benefit Analysis commonly cited are of the following nature:-

i) Perhaps the most fundamental criticism is that Cost Benefit Analysis only calculates the net social benefit, as its concern lies with economic efficiency rather than equity.

ii) Factors influencing the effectiveness of a Cost Benefit Analysis lie in the imperfections and uncertainties of the economic climate. For example, time lags in the adjustment of the private sector may mean that a project will be ultimately rejected despite the fact that it would have been worth undertaking at an earlier date.

iii) A Cost Benefit Analysis will only be as rigorous and effective as the ability, experience and political bias of the person conducting the study allow:

The course of action indicated by the analysis will be the one from those under consideration

that maximises welfare. But the analyst is often left to define the objectives and to decide what benefits and costs are relevent and how to assess them. Winch (1971) says that: "The choice (of costs and benefits) will depend partly on what is considered relevent and partly on what lends itself to ready statistical estimation."
And one cost may not be commensurate with another, or costs may not be commensurate with benefits. And double counting, particularly in wider social costs and benefits, frequently occurs.

Winch says (1971) of Cost Benefit Analysis:
" one cannot use it to achieve a perfect world, but only to improve the fit of one piece of an imperfect jigsaw puzzle." It is not enough. With criticisms as fundamental as those above surely it serves only to support the "imperfections"?

The Ford-Pinto case quoted below is a disturbing illustration of the sort of results that can be derived using Cost Benefit Analysis and the sort of uses to which it is put in valuing lives:-

The arithmetic that cost £66m

BENEFITS:

Savings	-	180 burn deaths, 180 serious burn injuries, 2,100 burned vehicles.
Unit Cost	-	\$200,000 per death, \$67,000 per injury, \$700 per vehicle.
Total Benefit	-	180x(\$200,000) + 180x(\$67,000) + 2,100x(\$700) = \$49·5 million.

COSTS:

Sales	-	11 million cars, 1·5m light trucks.
Unit Cost	-	\$11 per car, \$11 per truck.
Total Cost	-	11,000,000x(\$11) + 1,500,000x(\$11) =\$137 million.

These are the confidential calculations that convinced a southern Californian jury that America's giant Ford Motor Company had knowingly sold some two million of its Pinto 'sub-compact' cars with a potentially lethal fault in the design of its fuel tank. Last week the jury awarded 18-year-old Richard Grimshaw more than \$128 million - £66 million - in compensation and punitive damages for the terrible burns he suffered when the Pinto in which he was a passenger burst into flames after a minor accident.

The formula illustrated above is taken from a Ford internal memo of 1972. At the top are Ford's estimated 'benefits' to society, in financial terms, of saving the lives of the 180 people likely to be burned to death in a year and of preventing another 180 people from receiving severe burns, in accidents where the car rolls over and the fuel tank ruptures. Total saving: \$49·5 million. Below this is set the cost to Ford of altering its cars and light trucks to conform to the safety standards then being proposed by Congress to prevent petrol tanks exploding after an accident. Total cost \$137 million.

Ford's engineers concluded that the cost to Ford

> of the alterations were almost three times greater than the benefit of society that would flow from such alterations, "even using a number of highly favourable benefit assumptions." (Ford has never sold the Pinto in the U.K.)
> Richard Grimshaw's lawyers are convinced that the huge punitive damages resulted from the jury's determination " to punish Ford for risking human lives for profit".

Source: U.S. Press Report as quoted in Unit 11 of the Open University's Risk Course.

The alternative to Cost Benefit Analysis is the Cost Effectiveness method of choice between different programmes or projects. However, the major criticism here must be that this form of analysis provides no guide to action when there is a variety of project impacts of unknown value.

The debate about life valuation is both complex and confusing as its real concern lies with attempting to pin down the notion of value and attach a universally valid figure to life itself. As couched in its present form it is easy to condemn the debate as politically unacceptable. For who has the right to determine the worth of members of society and differentiate between them in terms of earning ability, age, sex, race, or even their own assessment of what their life value is or how much they would be prepared to pay (or forgo) in order to reduce the risk of premature death? Certainly the present criteria of value employed, namely vitality and wealth, should be rejected in favour of more equitable measures; but the debate itself cannot be ignored as to do so might tend to legitimate a discriminatory process.

It is unlikely that the search for a single universally acceptable life valuation will ever be successful as it involves all kinds of political and moral judgements, which reflect the complexity of existing views on equality, utility and value itself. Life valuation thus involves a system of values reflecting many different facets and points of view.

SECTION II

The problem treated as a simple costing exercise.

Chapter Six. The Research Method and the Costing Model Adopted.

6.1. The Research Method

Field research was carried out at two of the Electricity Supply Industry Area Board districts. The districts chosen were in Norfolk and London, contrasting rural and urban areas which revealed many different methods of working and many inherent environmental problems.

The two kinds of data were sought from the field research at district level; that is, details of the physical and human systems involved in the distribution of electricity to consumers; and a collection of 'case histories' of actual accidents. This data was then mapped onto the 'Costing Model', or framework, which can be used to derive estimates of actual costs of accidents to the industry. The model describes (mimics) the accident-sequence in terms of effects to which costs are assigned, (See 6.3. below).

Detail of the Method

The basis of the research method at this stage was informal interview, combined with observation.

An initial picture of the physical and human systems was derived from background information from the Electricity Council, and preliminary discussions with the District Managers and Functional Heads of Departments.

The compilation of case histories was the result of investigations of accidents selected from Area Board Headquarters. In this area of research data was collected as widely as possible, in several different ways:

a) details of the accident-consequences sequence were derived initially from accident report forms, and then followed up by informal interviews with injured employees, and others consequentially involved. This would typically involve: mates, foreman, engineers, safety representative and safety supervisors;

b) administrative-type data was gathered from available records found in diverse offices - details of length of absence, rate of pay, claims for compensation, accident statistics, overtime worked and the number of faults in specific periods were collected;

c) details of physical reinstatement to the system were derived from discussions with engineers and examination of relevant records. Various other, often more subjective, data was gathered from informal conversations and observations throughout the periods of research.

Outlines of the subject-areas around which questions were posed are detailed in Figure 8. overleaf. This method of research and the stages undertaken are described diagramatically in Figures 9 and 10 below.

Figure 8. Subject-bases of questions put to employees.

1. Exploratory Situation Based Questions.

These questions were aimed at establishing, as broadly as possible, the more immediate and direct consequences of the accident. Questions were framed to receive answers pertaining to the following areas:

a) Injury to Personnel:
personal consequences for the individual(s) involved;
loss of working time;
length of absence(s) from work;
medical treatment received;
investigations of incident;
consequences for prior committments of employees brought in to complete unfinished tasks;

b) Damage to Property;
damage or loss of Board's property: buildings, tools, equipment, plant...
damage or loss of non-Board property.

c) Interruption of Supply of Electricity:
loss or interruption of supply;

Further open questions allowed for other possibilities of direct consequences not encompassed by the above categories.

2. Questions Covering Potential Contingent Areas.

These questions were concerned with more indirect areas. Frequently the issues involved were relatively subjective and more contentious, thus, care had to be taken both in the phrasing and interpretation of question and answer. Subjects that can be included in this category around which questions were asked include the following:

consequences for injured on return to former job;
compensation claimed for;
loss of productivity;
perceived risk and frequency of incident occuring;
consequences for design of plant and equipment and procedures for working.

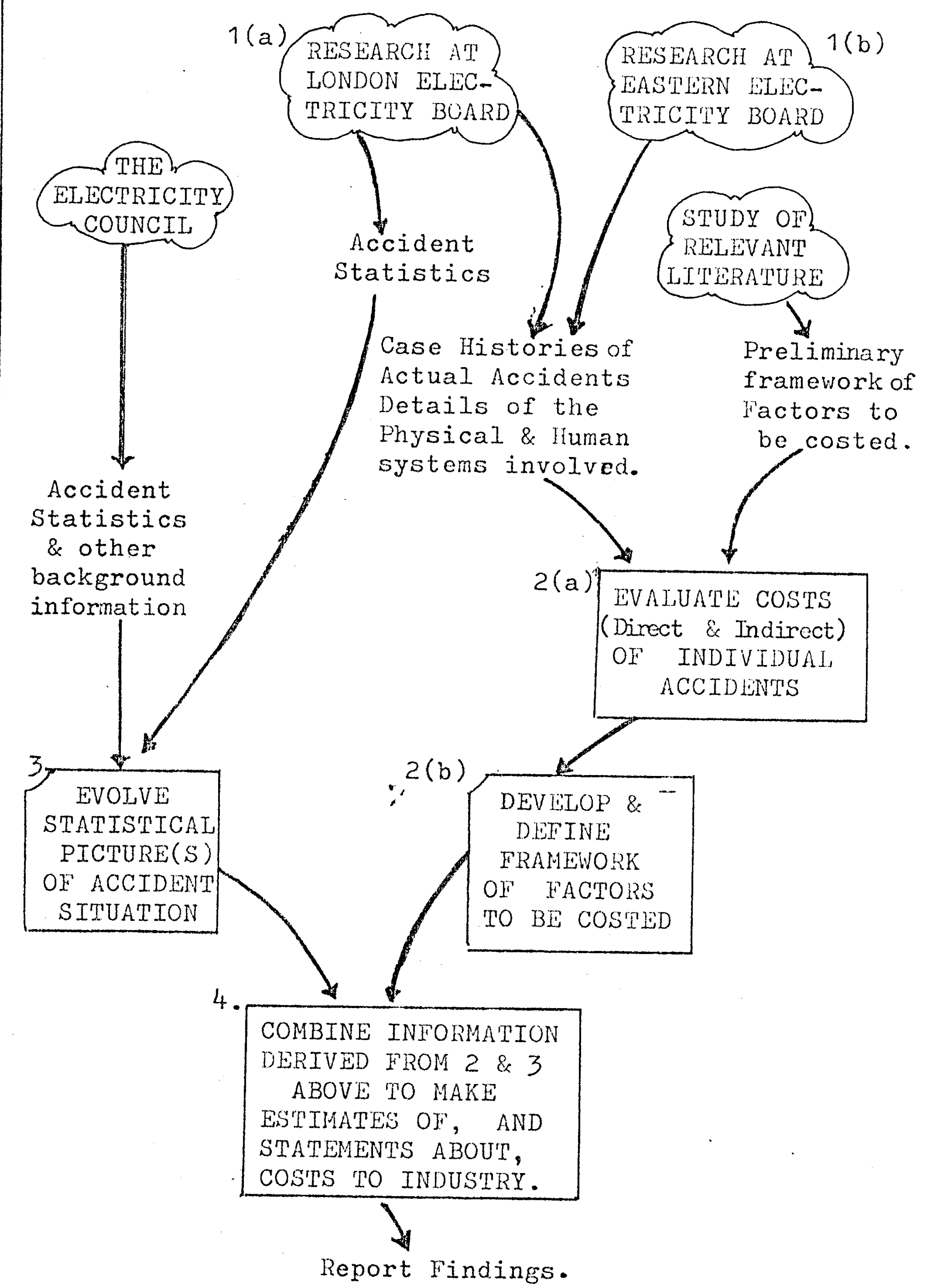


Figure 9. Research Method; outline of stages undertaken.

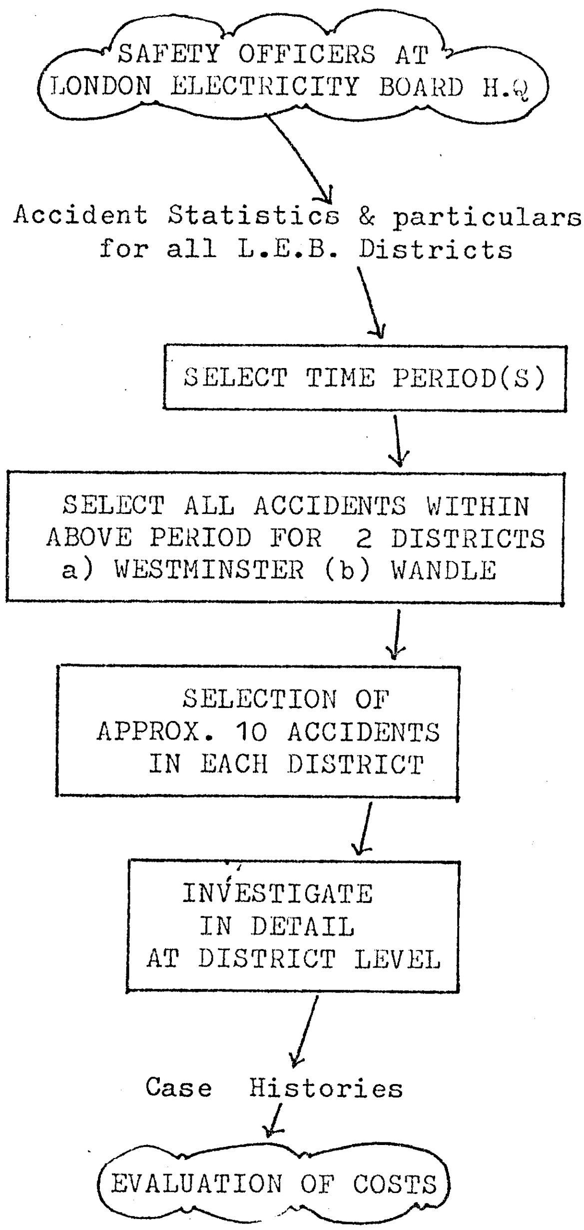


Figure 10. Outline of Method of Research, as at London Electricity Board.

6. 2. Appropriate Cost Categories.

As the study is only concerned with costs that accrue to the Electricity Supply Industry all other classes of costs have been excluded from estimates made for the Industry. It should be noted, however, that these excluded cost categories can not be ignored as they represent substantial burdens for individuals involved and for society as a whole. Excluded costs to be noted include the following:

i) individuals' and families' costs (loss of income, and other less readily accountable costs such as the costs of pain and suffering, and curtailment of the enjoyment of life.);

ii) costs of other industry's lost production;

iii) and all the costs that accrue to society generally, which include medical service costs, costs of National Insurance, legal costs and the costs of lost production and consumption.

The breakdown of costs into those that form monetary costs accruing solely or largely to the Electricity Supply Industry, and the general major categories of costs accruing not only to the Industry but also to the individual and 'society' (in various forms) are considered in Figures 11 and 12. Note should be taken of the clear cut and the overlapping areas of cost.

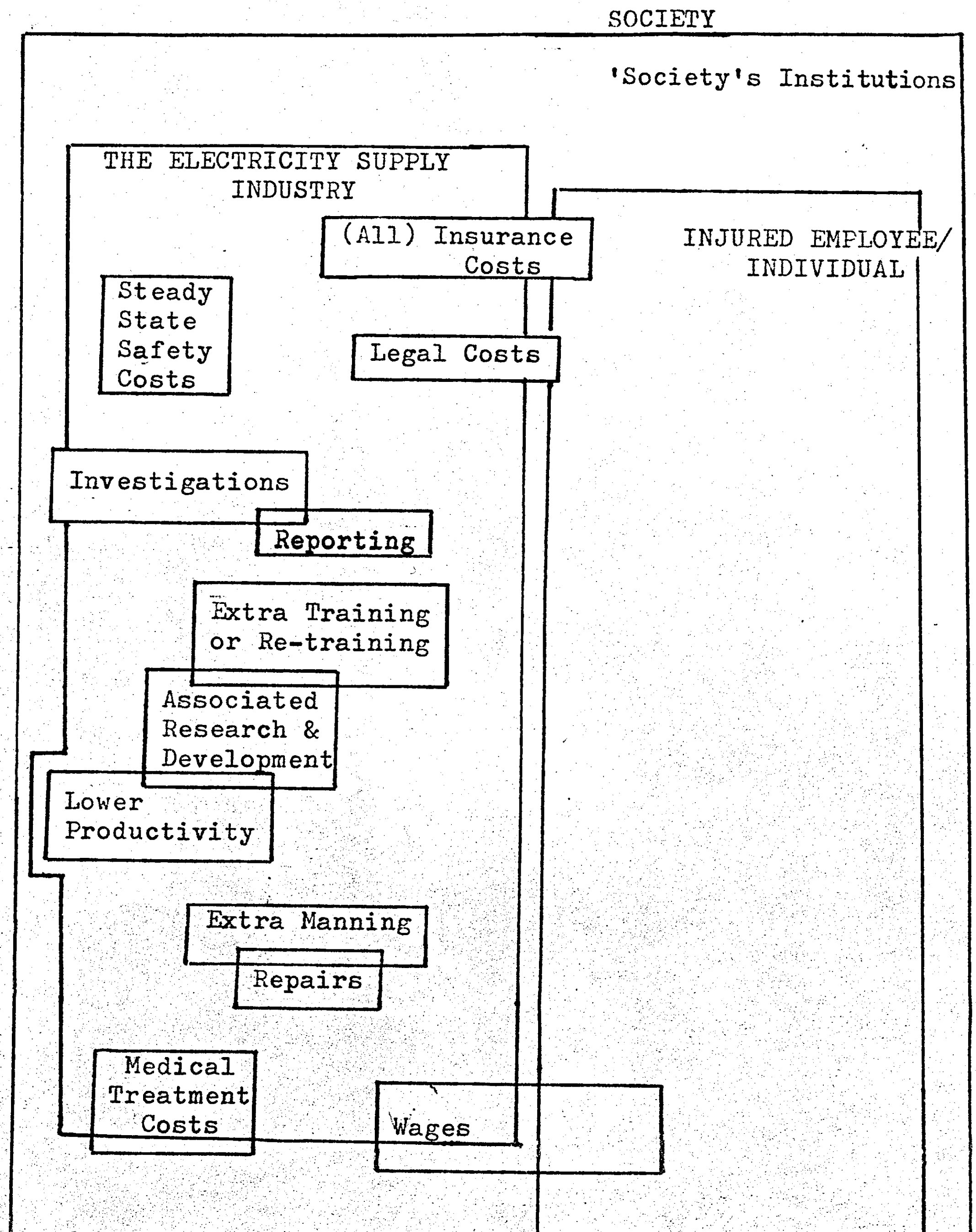


Figure 11. Costs that Accrue to the Electricity Supply Industry.

Note

Refer also to Figure 12 for major cost categories that fall on individuals, their families and society as a whole.

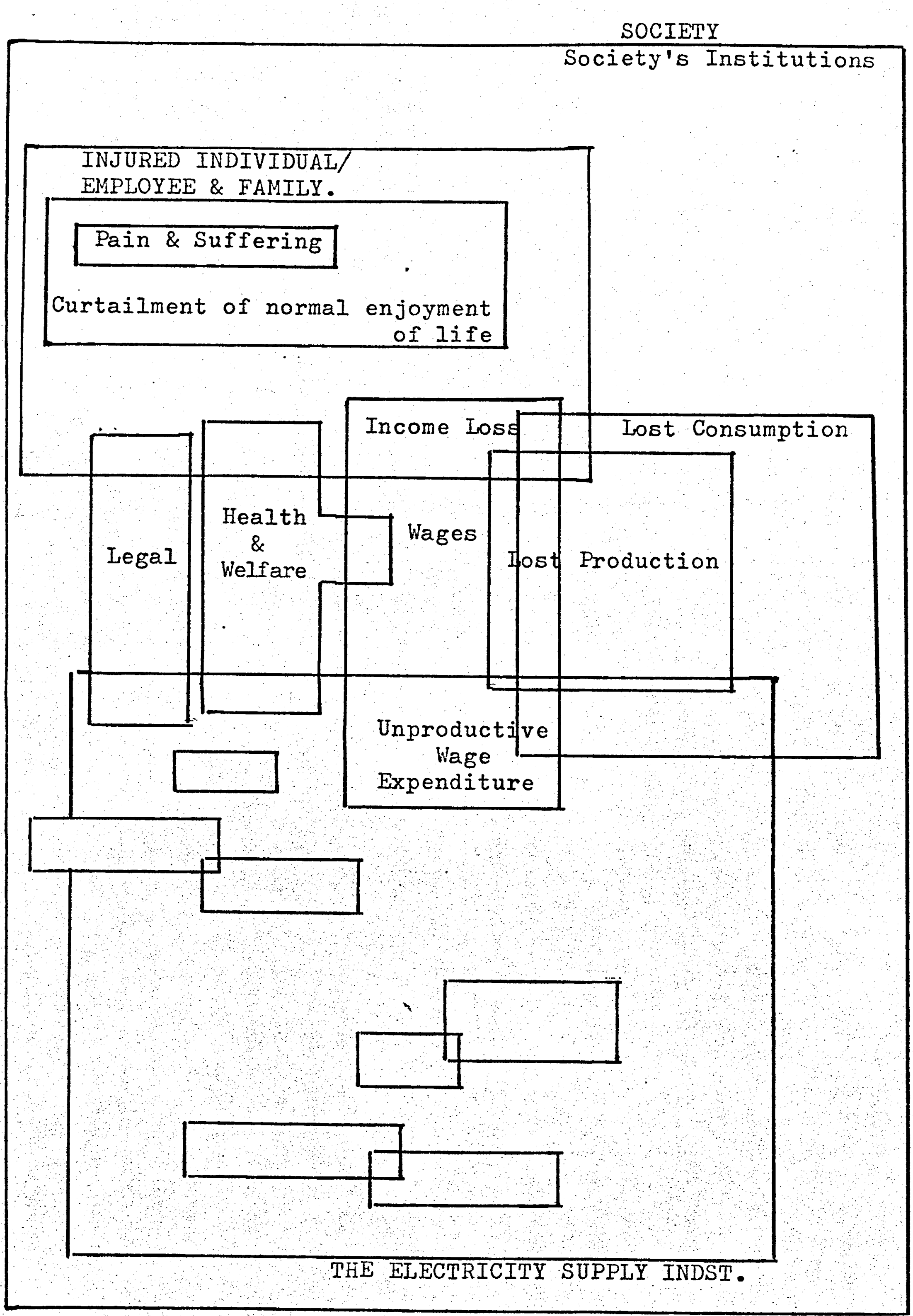


Figure 12. Summary of Major Cost Categories.

Note

Figure 11 illustrates the specific costs that accrue to the Electricity Supply Industry, shown here as The Unnamed blocks.

The cost categories were arrived at from analysing the data assimilated during the field research. Classes of cost were initially analysed in two different ways:

Method 1. By description of the elements involved in:

a) ensuring the stability of maintaining effective plant and manpower to which costs attributable to safety can be attached; and:

b) the consequential costs arising out of a break in stability caused by an accident.

These two major classifications can be described as:

a) prevention costs; and (b) resultant costs.

Method 2. By division of costs into:

a) direct costs, that is the immediate results of the accident to which costs may be attached, and:

b) indirect costs, that is secondary or consequential results to which costs may be attached.

Method 1. is detailed below, whilst Method 2. is described diagrammatically in Figure 13. For use with the model, (described in 6.3 below) Method 2. was used; as can be seen this method contains the 'Resultant Costs' of Method 1 with only aspects of the Prevention costs.

Method 1.

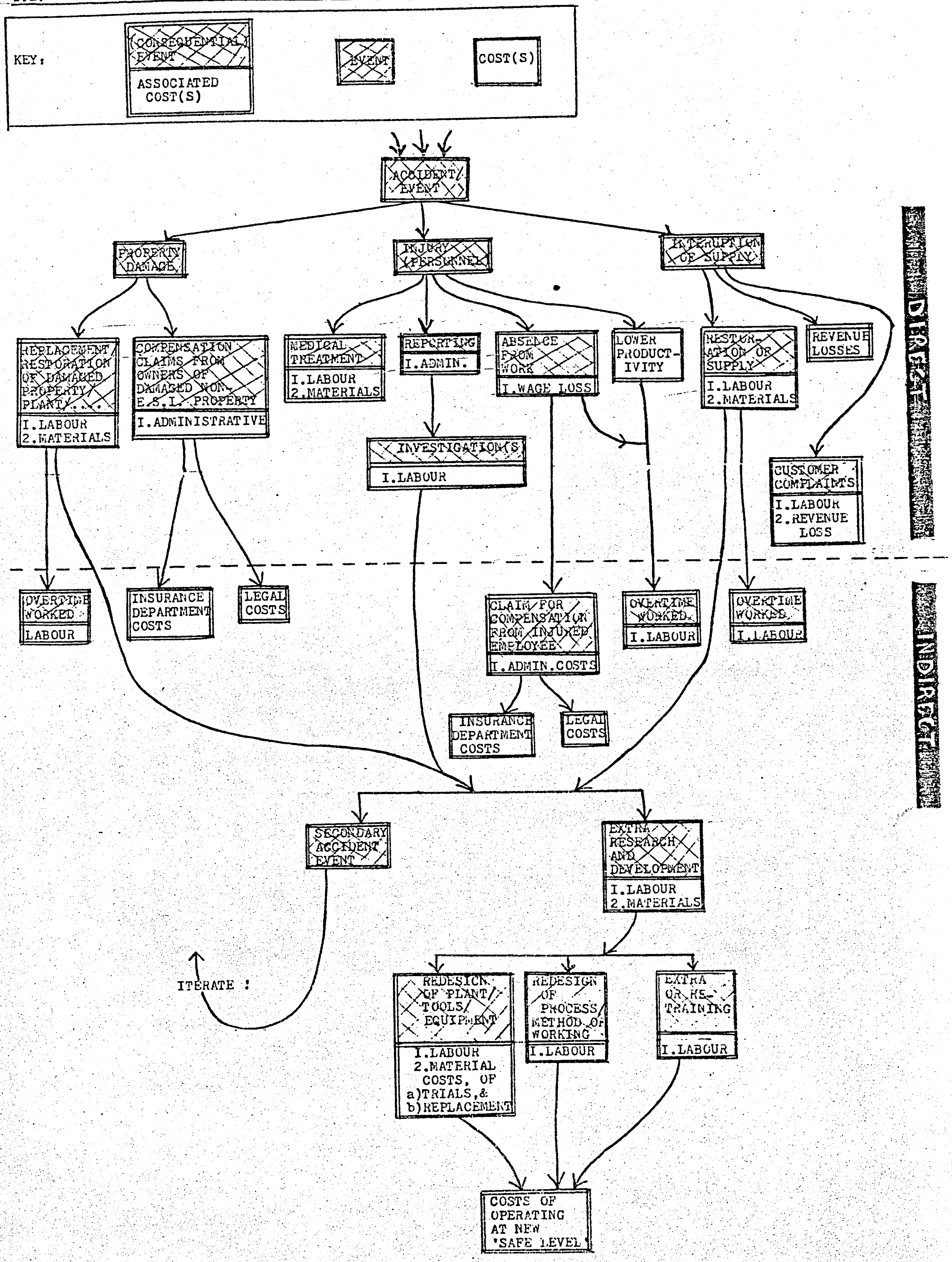
A. Prevention Costs

A.(i) Design Costs: (1) Building in a shutdown capability for features that are potentially dangerous.

	(2) Design safety margins. (3) Built in protection from processes e.g. machine-guards. (4) layout-cost of workshops, stores etc. attributable to safety.
A.(ii) Operational Costs:	(1) Costs of Safety Branch, and Safety personnel at Board level, and all activities directly associated with Safety. (Includes: all salaries, trade publicity, protective clothing.) (2) Medical and First-Aid materials and training. (3) Cost of (extra) manning specifically for safety reasons. (4) Cost of operating at stated 'safe' levels, e.g. temperature, speed.
A.(iii) Consequence limiting & Planning Costs	(1) Insurance department costs. (2) Research and development costs, relating to safety-issues directly, or any safety-costs contained in other unrelated research and development.
B. <u>Resultant Costs.</u>	
B.(i) Routine post-factum costs:	(1) Wage-losses. (2) Associated administrative costs of reporting.
B.(ii) Contingent post-factum costs:	(1) Loss of revenue. (2) Costs of medical treatment (labour and materials). (3) Investigation costs. (4) Legal costs. (5) Extra and/or increased insurance costs. (6) Costs of repairs (labour and materials). (7) Costs of overtime worked as a result of incident. (8) Cost of lower productivity. (9) Cost of extra or re-training. (10) Associated extra research and development costs.

Figure 13.

ANALYSIS OF COSTS (2.)
I.E. 'DIRECT' AND 'INDIRECT' COST CATEGORIES.



6. 3. The Model.

The Costing Model (as depicted in Figure 15) was constructed and used by the author of this thesis as a framework for interpreting and evaluating the data collected. The Model enables actual figures to be arrived at for particular costs and thus conclusions may be drawn as to high and low cost areas resultant from any accident or class of accident: For example, from actual costing exercises carried out it can be seen from total cost figures that the highest costs for the industry are to be found within the branch of the model labelled "Effects to Personnel". Use of the model is described in Chapter 7.

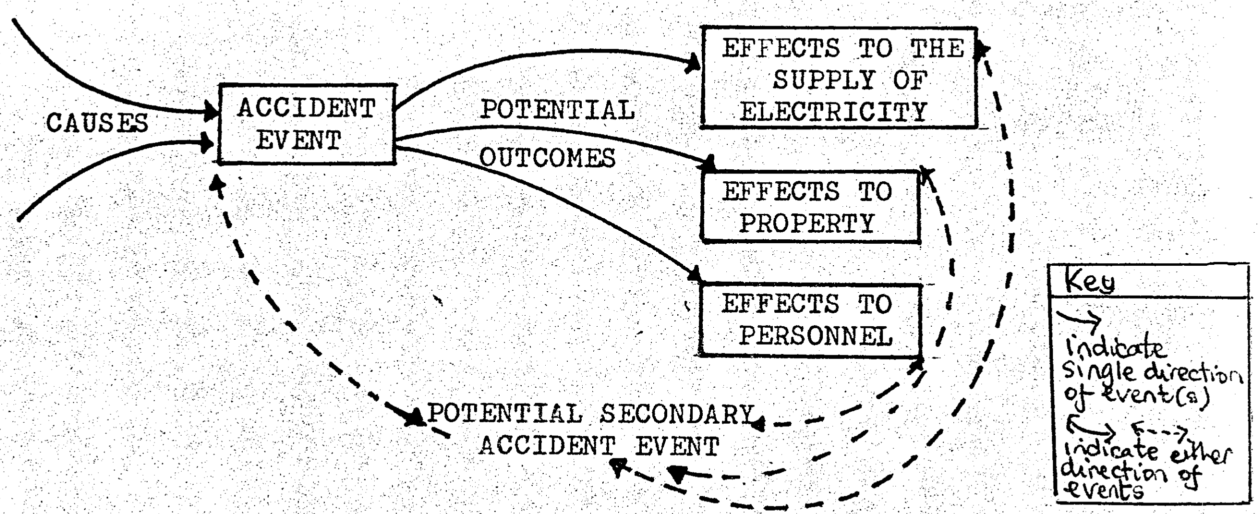


Figure 14. The three major categories of potential outcome of an accident, as used in the model.

The diagram above (Figure 14) indicates the three major categories of potential outcome of an accident, within

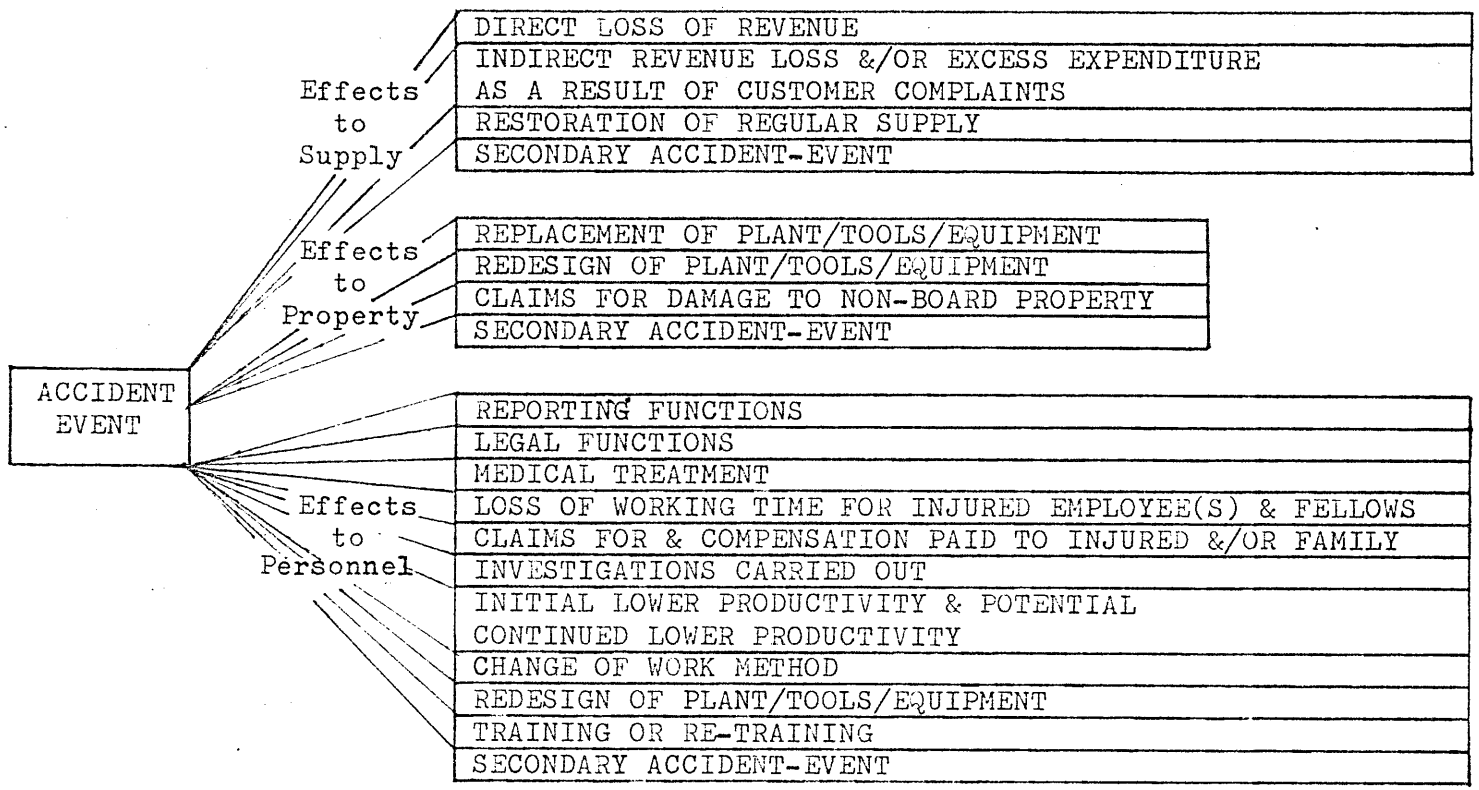
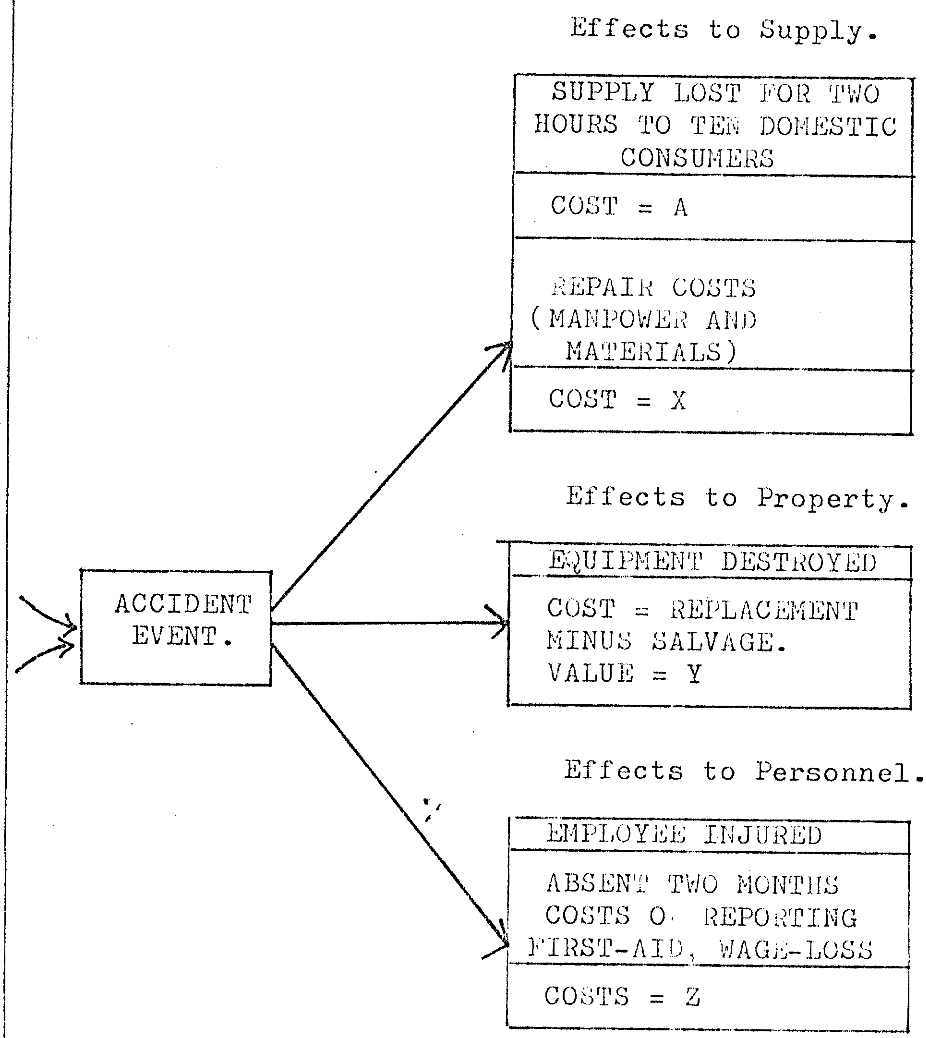


Figure 15. The Costing Model: Framework of Potential Post-Factum Costs for the Electricity Supply Industry Resulting from an Accident.

(Note the exclusion of costs that fall on the individual and his/her family; costs to other industry; and costs to society).

each 'branch' or major category, there are many possible outcomes - different combinations of which will occur resultant upon an accident - and to each outcome a cost may be attached.

Figures 16 and 17 show examples of use of the model using a hypothetical example (Figure 16) and then a real accident (Figure 17) from those studied whilst engaged on field research with the Industry.

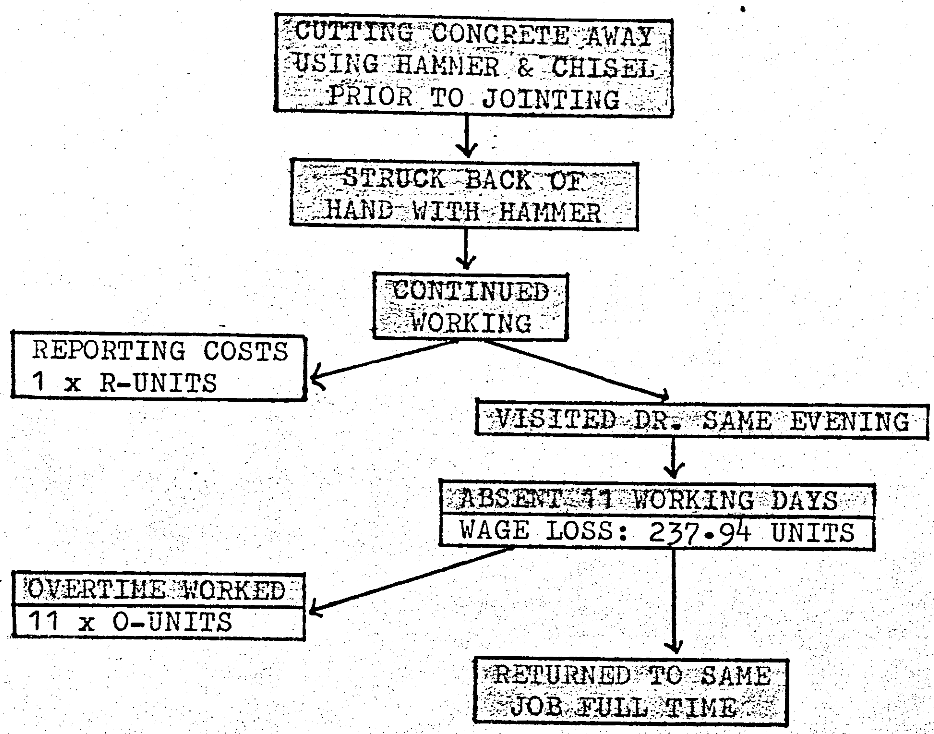


TOTAL COST OF ACCIDENT: = A PLUS X PLUS Y PLUS Z

Figure 16. An Example of the Use of the Model.

LONDON ELECTRICITY BOARD. WANDLE DISTRICT. CASE HISTORY.

JOINTER. ACCIDENT CLASSIFICATION: USE OF HAND TOOLS.



Total Costs: 237•94 UNITS, PLUS 1x R-UNITS, PLUS 11 O-UNITS

Plus Other 'Non - E.S.I' Costs:
Costs to the individual of pain & suffering
Costs to Society of medical treatment & DHSS payment.

Figure 17. An example of use of the Model: An actual accident Case History.

For KEY to diagram and 'Unit' Costing, refer to key-page. (Page 101)

Chapter Seven. Using the Model.

7.1. The data available and use of it.

To whatever end, examination of accident statistics are always contentious, as the numbers themselves reveal little about the many variables involved in every situation.

The quotation below, taken from Darrell Huff's book on the art of lying with statistics is a graphic example of the misuse which can be made of numbers as indicators of truths.

PICKLES WILL KILL YOU

Pickles will kill you: Every pickle you eat brings you nearer to death. Amazingly the 'thinking man' has failed to grasp the terrifying significance of the term "in a pickle". Although leading horticulturists have long known that Cucumis sativus possesses an indehiscent pepo, the pickle industry continues to expand.

Pickles are associated with all the major diseases of the body. Eating them breeds wars caused by pickles. There exists a positive relationship between crime waves and consumption of this fruit of the Cucurbit family. For example:

Nearly all sick people have eaten pickles. The effects are obviously cumulative.

99.9% of all people who die from cancer have eaten pickles.
100% of all soldiers have eaten pickles.
96.8% of all communist sympathisers have eaten pickles.
99.9% of all the people involved in air and auto accidents ate pickles within 14 days preceding the accident.
93.1% of juvenile delinquents come from homes where pickles are served frequently.

Evidence points to the long-term effects of pickle eating:

> Of the people born in 1839 who later dined on pickles, there has been a 100% mortality.
>
> All pickle eaters born between 1849 and 1859 have wrinkled skin, have lost most of their teeth, have brittle bones and failing eyesight - if the ills of eating pickles haven't already caused their death.
>
> Even more convincing is the report of a noted team of medical experts: rats force-fed with 20 pounds of pickles per day for some 30 days developed bulging abdomens. Their appetites for WHOLESOME FOOD WERE DESTROYED.
>
> In spite of all the evidence, pickle-growers and packers continue to spread their evil. More than 12,000 acres of fertile soil are devoted to growing pickles. Our per capita yearly consumption is nearly four pounds.
>
> Eat orchid petal soup. Practically no one has as many problems from eating orchid petal soup as they do from eating pickles.
>
> (Source: Darrell Huff "How to Lie with Statistics".)

However, classifications of accident statistics enable use to be made of what otherwise would appear as unwieldy lists of numbers. For the purpose of utilising the model to cost accidents in the Electricity Supply Industry, the standard form of classification that is readily available throughout the Industry was adopted. Thus the Industry's analysis of accidents in terms of 'causation' was used. These statistics relate to the industrial/manual staff, for they make up the group of employees for whom accidents are statistically significant.

The statistics are divided into the following categories:

1) Machinery (hand and power operated)
2) Transport (including mechanical truck)
3) Electricity
4) Explosions and fires
5) Hot substances
6) Poisonous and corrosive substances, gassing etc.
7) Persons falling
10) Handling objects (by hand or by hand truck)
11) Hand tools
12) Miscellaneous.

Tables of accident statistics analysed in this way are to be found in Appendix Number 4 and their use in conjunction with the model is explained in 7. 3.

Although the Industry's standard form of classification has been adopted for simplicity, other factors apart from causation can be seen to be important in assessing costs. An example of this can be seen by examination of the category of accidents selected at the outset of the study as being of major concern; this is the class of accidents to which 'Electricity' is stated as being causal. Although these accidents only form approximately six to seven per cent of the total number of accidents, their significance lies in the high proportion of these six or seven per cent that result in serious injuries and high costs.
Other classifications apart from causation which could usefully be employed in the analysis of accident ststistics include the following factors:

1) Agents of injury
2) Nature of injury
3) Severity
4) Length of absence from normal/usual employment

5) Time of day of accident
6) Nature of task involved
7) The frequency of accidents for particular tasks
8) The number of accidents related to total amount of 'work' performed in terms of hours/production level...
9) Injured persons' perceptions of the nature of the risks involved.

7. 2. The Unit Costing Approach.

The Unit Costing approach has been adopted to illustrate the type and scale of costs involved.

Case histories of actual accidents studied whilst engaged in field research at London Electricity Area Board are described diagramatically in Appendix Number 2. Using the cost categories from the model (see Chapter 6 above) to analyse the accident data summarised in the Case Histories it can be seen that the vast majority of accidents routinely result in a combination of the following costs:

'n' UNITS of Wage-Loss Cost

'n' O-UNITS of the cost of associated Overtime

'n' R-UNITS of the cost of associated Repoting

Other, generally more severe, accidents result in the above costs, PLUS differing combinations of the following:

'n' I-UNITS of the cost(s) associated with Investigation

'n' M-UNITS of cost associated with Material losses

'n' P-UNITS of cost which represented Revenue losses 'n' C-UNITS of cost which are costs concerned with Changes in, for example, method or procedure and any other related research and development expenditure.

'n' L-UNITS of costs associated with Legal and Insurance costs, which will be largely administrative.

The Case History below (taken from Appendix 2.) is a typical accident involving handling, and resulting in Units of Wage-Loss costs, Overtime costs and associated Reporting Costs. The diagram illustrates the technique used to order the relevant accident data and the connection of the Unit Costing approach to the categories of cost of the model.

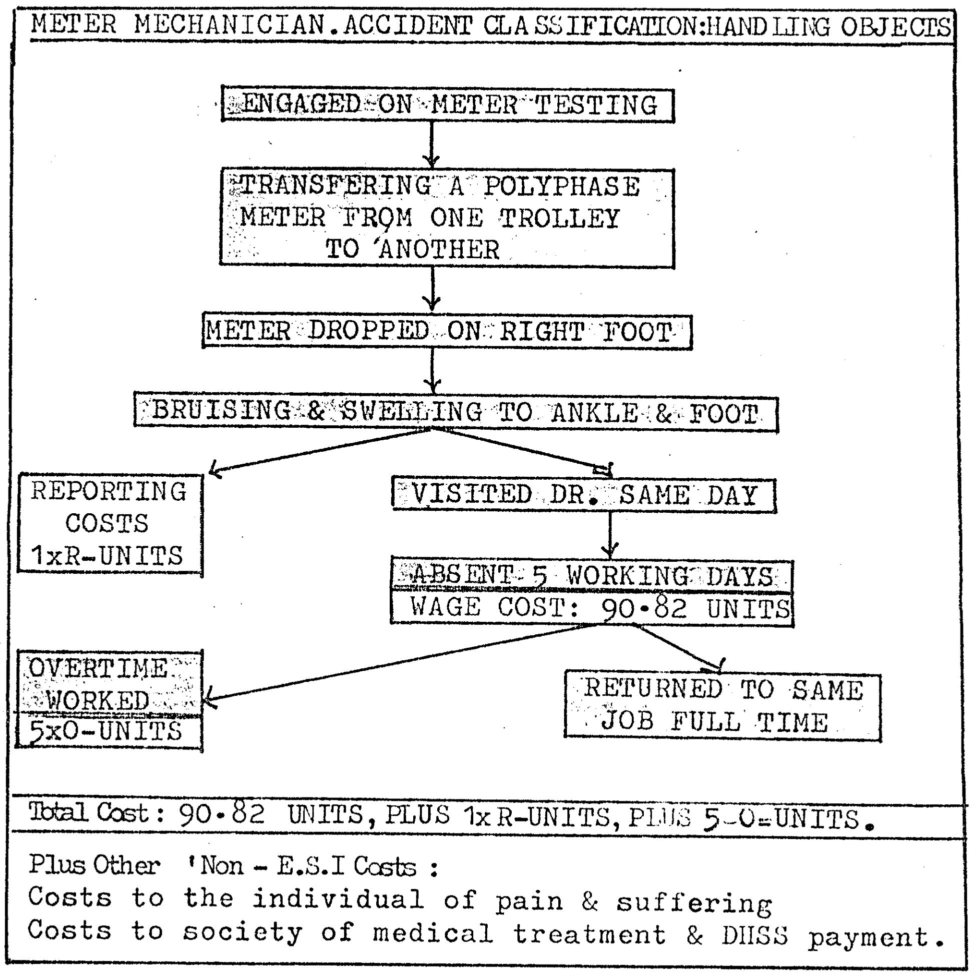


Figure 18. An example of an accident Case History.

It should be noted here that the relationship between the different Units of cost will be subject to frequent change; and that in some instances separate cost elements can not simply be added.

Values for the Cost Units can be derived as follows:

'Base' Units:

Units of Wage-Loss Cost

These Cost Units represent the amount of expenditure on wages paid out unproductively due to absence from work resulting from an accident. They are used as 'Base Units' as they are simply calculable. A unit is derived by calculating the total 'oncosted pay' (which includes the employers' contributions) for the period of absence and subtracting the DHSS payment.

O-Units

Units of the Cost of Associated Overtime.

Each O-Unit represents the cost of overtime worked for each working day 'lost' as a result of an accident.

It could be expected that each day lost due to an accident would normally be replaced by one extra days'. overtime. But in fact the relationship between days lost and overtime worked is particularly variable and subject to change on account of 'external' factors such as the manning level and inherent time-lags; the connection is certainly not one - to - one; as Figure 19 overpage helps to illustrate:

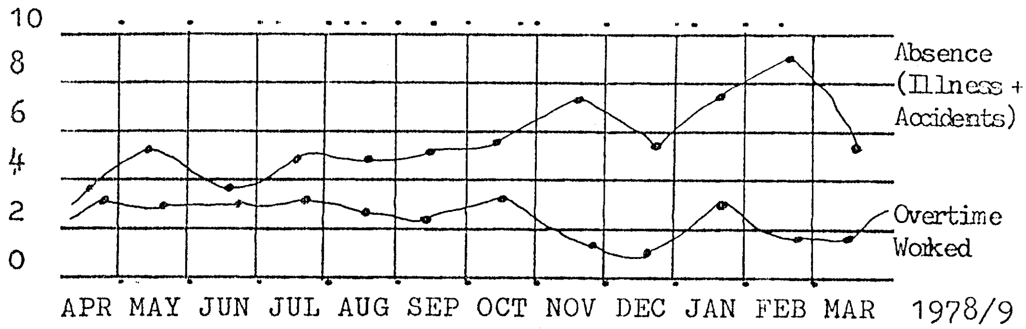


Figure 19. Total overtime worked and absence from work due to illness and accidents in one Area Board District 1978/9 expressed as percentage of normal working time.

(It is recognised that other factors unrelated to the number of accidents also influence the amount of overtime worked, for example the demand for the supply of electricity, the number of new customers and the number of so-called 'Abnormal Incidents').

R-Units:

Units of the Cost of Associated Accident Reporting.

Each R-Unit represents the cost of standard reporting. The costs involved are administrative, and largely represent 'time and paper' costs. These can be calculated as follows:

R-Units

1 R-UNIT

Reporting associated with less severe '3-Day' Accidents: Accident Book & Standard Report Form completed, sent to local Admin. Department who send to Dept. Heads Safety Committee & Area Board HQ... to Electricity Council Safety Branch...

2 R-UNITS

Standard reporting as with '1 R-UNIT', plus direct notification of District Control Engineer responsible for Safety matters, Safety Supervisor, Relevant Safety Representative.

3 R-UNITS

Reporting as in 1 and 2 R-UNITS, plus direct notification of any Area Board (Safety & Engineering Personnel & their subsequent involvement, plus any direct notification of Electricity Council Personnel and/or any other individuals & bodies (e.g. Factories Inspectors, Dept. of Energy.)

Appendix 3 contains detailed information about standard and statutary accident reporting obligations and procedures. Figures 41 and 42 in this Appendix relate closely to the levels of reporting represented by 1 R-Unit, 2 R-Units and 3 R-Units as they are diagramatic illustrations of the procedures followed for accidents of varying severity.

I-Units:

Units of the Costs Associated with Investigations.

These costs will largely be Wage-Loss costs and may be calculated as such where appropriate. Occasionally investigations may include other Extra-Ordinary costs, such as costs of particular independent surveys or other calculations, for example, and when this occurs these costs will have to be calculated and included as 'Additional Costs'.

M-Units:

Units of Cost Associated with Material Losses.

These are costs arising from Material losses as the result of an accident. The Industry will be responsible not only for its own material losses but also other industry's and members of the public's losses resulting from their actions. The costs involved will be calculated by subtracting the salvage value from the replacement cost or by calculating an affected industry's revenue losses caused by an accident for which the Electricity Supply Industry is held responsible. But in practise most material losses are compensated for by the industry's insurance cover. Thus for the Electricity Supply Industry most material losses in fact represent administrative costs.

<u>P-Units:</u>

<u>Units of Cost Representing Revenue-Losses for the Electricity Supply Industry.</u>

These costs are not always simply calculable. The amount of Revenue-Loss involved will depend significantly on factors such as the time of year and the type of consumers affected.

<u>C-Units:</u>

<u>Units of Cost Associated with Change.</u>

These units of cost are concerned with research and development costs arising out of accidents and also the costs of any changes that may occur, possibly but not necessarily, as a result. Changes may result, for example, in the design and manufacture of a particular piece of machinery that is used which may entail replacement on a vast scale. Such costs are difficult to include when estimating actual costs, but they should not be ignored as they can represent vast sums.

L-Units:

Units of Cost Associated with Legal and Insurance Costs.

These costs largely represent administrative costs for the Electricity Supply Industry.

Fatalities

It should be noted that Fatalities will frequently involve peaks of costs, and could perhaps be included as a separate classification.

7. 3.

Application of the Unit Costing Approach: a Worked Example

The accident data, as summarised in the Case Histories in Appendix Number 2. were used in conjunction with the model and the Electricity Supply Industry's accident statistics to evaluate actual costs by application of the Unit-Costing approach.

The example overpage is an illustration of the method and it should be observed that estimates have been made in some instances. Unit-Costs relate to data collected during 1979 and are of course likely to vary over time.

ACCIDENT CATEGORY	TOTALS IN AREA BOARDS	'TYPICAL' UNITS OF COSTS
1 Machinery	133	150 UNITS, 1 R-UNIT, 10 O-UNITS, 30 M-UNITS
2 Transport	192 +2	As above, PLUS 3/4 L-UNITS
3 Electricity	141 +5	2525 UNITS, 3 R-UNITS 134 O-UNITS
4 Explosions, Fires...	11	150 UNITS, 1 R-UNIT, 10 O-UNITS, 50 M-UNITS
5 Hot Substances	79	90 UNITS, 1 R-UNIT, 5 O-UNITS
6 Poisonous & Corrosive Substances...	10	150 UNITS, 1 R-UNIT, 10 O-UNITS
7 Persons Falling	658	178 UNITS, 1 R-UNIT, 11 O-UNITS
8 Stepping on, or striking against objects.	371	642 UNITS, 1 R-UNIT, 41 O-UNITS
9 Objects Falling	181	107 UNITS, 1 R-UNIT, 5 O-UNITS
10Handling Objects	862	144 UNITS, 1 R-UNIT, 6 O-UNITS
11Hand Tools	334	238 UNITS, 1 R-UNIT, 11 O-UNITS
12Miscellaneous	215 +1	200 UNITS, 2 R-UNITS, 15 O-UNITS, 10 M-UNITS
TOTAL	3187 +8	(+ denotes fatalities)

Figure 20. Summary of accidents involving more than three days absence from normal employment. 1st April '76 - March '77

On account of imperfect knowledge of some of the variables involved in calculating the Units of Cost, the following assumptions, based on research into typical time, labour and material costs involved, were made to derive an estimate of total actual costs. Again these assumptions are likely to vary over time and thus would have to be re-assessed in the light of changing circumstances.

1	(base) Unit	=	£1			
1	R - Unit	=	2 (base) Units	=	£2
1	O - Unit	=	1 (base) Units	=	£1
1	M - Unit	=	1 (base) Unit	=	£1
1	L - Unit	=	$1\frac{1}{3}$(base) Units	=	£1·33

Taking the data from the accident Case Histories as typical and substituting the numbers in brackets below as estimated real costs based on the above assumptions for 1976-77 figures; the following estimate of 'Total Typical Costs' can be made:

MACHINERY	133x(150 plus 2, plus 10, plus 30)=25536
TRANSPORT	194x(150 plus 2, plus 10, plus 30, plus 1)=25537
ELECTRICITY	146x(2525plus 6, plus 134)=22095
EXPLOSIONS...	11x(150 plus 2, plus 10, plus 50)=2332
HOT SUBSTANCES.	79x(90 plus 2, plus 5)=7663
POISONOUS SUBSTANCES..	10x(150 plus 2, plus 10)=1620
PERSONS FALLING.	658x(178 plus 2, plus 11)=125678
STEPPING ON..	371x(642 plus 2, plus 41)=254135
OBJECTS FALLING.	181x(107 plus 2, plus 5)=20634
HANDLING OBJECTS.	862x(144 plus 2, plus 6)=131024
HAND TOOLS	334x(238 plus 2, plus 11)=83834
MISC.	216x(200 plus 4, plus 15, plus 10)=49464

PLUS (f) a factor representing other unquantified costs, such as C - Units.

Thus an estimate of the total cost of accidents, using 1976 - 1977 statistics = £749552 (plus (f))

Chapter Eight. Costing Conclusions.

8. 1. Costing Conclusions.

Using the method and the model, as described above, actual data on the costs of accidents (both for the total number and also for particular categories of accidents) can be derived. But the validity of such data, and the use to which it can or should be put remains a contentious issue. Similar criticisms to some of those made about other studies on the value of life and costing accidents remain relevant:

1) Assumptions frequently have to be made, as in the following instances:
2) The small size of the sample on which the assumptions are based.
3) The number and type of assumptions that become necessary tend to invalidate the exercise.
4) The complexity and intermixing of the variables to be costed may lead to nonsensical results.
5) The exercise of costing accidents from such a narrow perspective may similarly lead to insignificant conclusions. This narrowness of perspective may be the result of tacit acceptance of an incorrectly stated problem.

8.2. The Need and Value of a Wider, Holistic Approach.

The criticisms that have been made above of using a relatively narrow and reductionist approach lead naturally to a questioning of the method and a search for an alternative, wider approach. Hence, the systems context and the examination in the next section (Section III) of the value and applicability of a soft and hard systems method to the Electricity Council's problem.

The application of systems thihking to a wide variety of problems in the context of many different disciplines has been going on for the last forty years or so. The development of the approach can be traced to two different sources:-

S.P. Nikoranov (1973) says that the initial impetus was with the development of national defence systems in the years of the Second World War, and the post-war years. This branch of systems can be called 'control and communication' (Checkland 1981). The second source, the ideas which Checkland (1981) calls 'emergence and hierarchy' lies in the biological sciences. But systems and holism are not new concepts, it is claimed that the formal philosophical basis of holism can be attributed to the classic philosophy of the Greeks.

Existing systems methodologies range from 'harder' ones with roots in engineering and management science to 'softer' methodologies developed to take account of less readily definable and quantifiable aspects typically to be found in problems of social and human-activity organisations. The debate about when and where a soft or hard methodology is appropriate and the differences between them becomes complex in the 'grey' areas.
The task of choosing an appropriate methodology to suit a particular situation is a skill which develops with use. However, there are several guiding factors which can be utilised - for example: If the task and objectives have been formulated and the formulation seems acceptable then a harder methodology is usually more applicable. However, if there is a debate over objectives and the problem situation seems rather ill-defined then generally a softer systems methodology will be more appropriate .

The value of a holistic approach can be summarised by looking at some of its characteristics:

A systems methodology:-

i) contains a statement of the objectives of the study which are open to review and modification;

ii) generally contains feedback mechanisms, i.e. a stage may well be passed through several times before the investigation is complete;

iii) poses open-ended questions with many possible answers, rather than providing guidelines for only one possible type of answer;

iv) is, or provides, the means for the investigator or analyst to achieve a complete plan for studying a situation, which encourages all and any important avenues to be explored and considered.

SECTION III

Exploration of alternative methodologies.

Chapter Nine.

Discussion of the Applicability of Softer Systems Methodologies to the Electricity Council Project, with Reference to the Checkland's Methodology.

9. 1. Introduction to, and description of, the Methodology.

Checkland's methodology (1972) is ranked on the softer side of the systems movement, together with methodologies such as those of C.W Churchman (1968), and R.L. Ackoff (1974).

Checkland's methodology was developed in the Systems Department of the University of Lancaster as a result of frustration experienced with attempts to apply harder, more functionalist (systems/engineering/operations research) methodologies in soft problem situations - that is problems of and in, human-activity systems. The methodology the group at Lancaster were attempting to apply to such problems was previously that of Jenkins (1969 'The Systems Approach'), and Checkland found this inappropriate along with other existing methodologies, for wider application to softer problems, in organisational problems for example. He argued against contemporary thought that all problems ultimately reduce to the evaluation of the efficiency of alternative means for a designated set of objectives, saying:-

"It became clear that the present research was to be concerned not with problems as such but with problem situations in which there are felt to be unstructured problems, ones in which the designation of objectives is itself problematic."
(Checkland 1981)

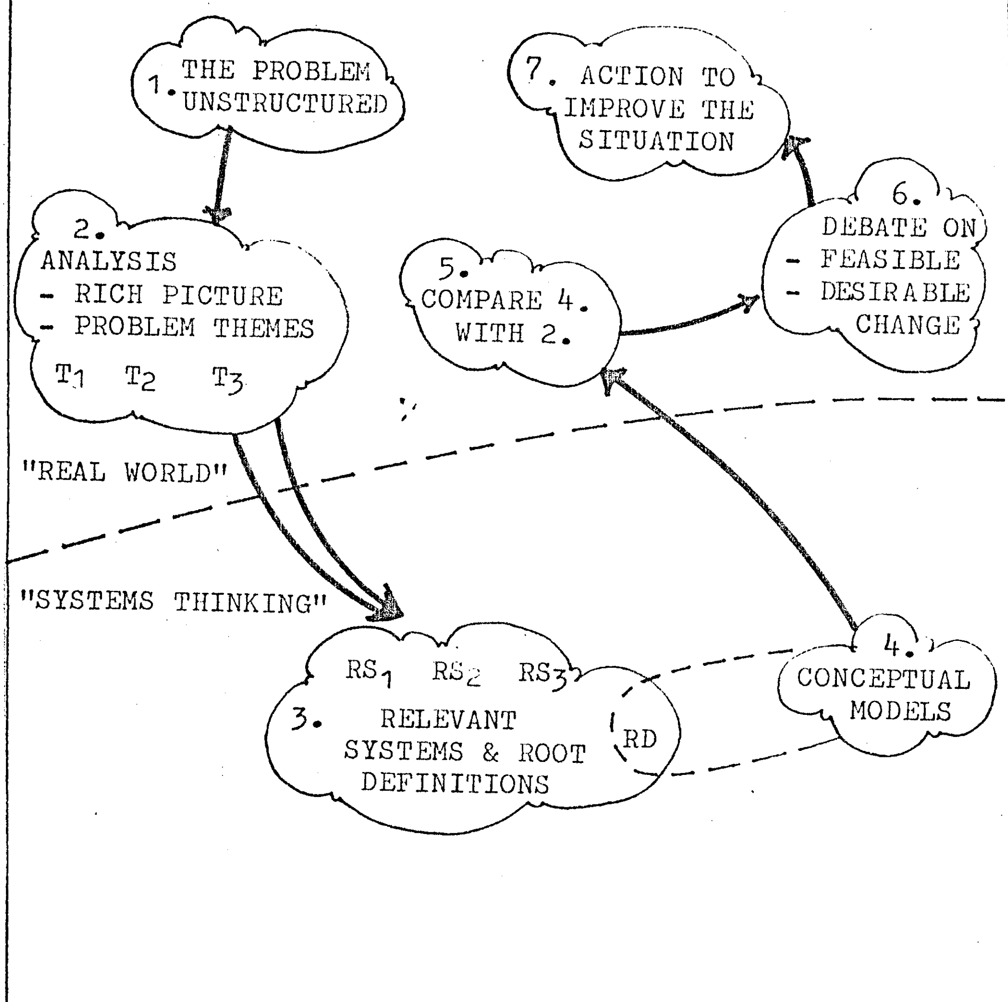


Figure 21. The Basic Stages of the Checkland Methodology

The methodology can be represented, as shown in Figure 20 as a chronological sequence. However, this sequence does not have to be followed rigidly, and the methodology may be seen as a framework to work within: it is quite possible, for example, to start the methodology at Stage 4, (the conceptual model building stage); and iteration and backtracking are an essential part of the process.

Stages 1 & 2 involve understanding and expressing the situation in which the problem is perceived to exist.

Stage 3 involves naming some systems that appear to be relevant to the problem and giving concise definitions of what they are.

Stage 4 consists of making conceptual models of the human-activity systems named and defined in Stage 3. Here structured sets of verbs are assembled describing the minimum necessary activities required in human-activity systems.

Stage 5 Here the models from Stage4 are brought into the 'real world' and set against the perceptions of what exists there. This generates the discussion in:-

Stage 6 which leads to the description of desirable and feasible changes.

Stage 7 involves taking action based on changes arrived at in Stage 6.

This 'end' can be seen as the 'new problem' and the process continues.

9. 2. Applying the Checkland Methodology to the Electricity Council Project.

Checkland (1981) in documenting the development of his methodology through over a hundred attempts at using it and drawing general lessons from the experience, says that five different kinds of study with five different aims can be identified, they are:-

systems design; action to improve an ill-defined problem situation; survey of an area of concern; and clarification of concepts.

In discussion of the applicability of Checkland's methodology to the Electricity Council Project the first two of these five perspectives have been arbitrarily chosen to illustrate what can be learnt from this approach.

9. 2. (i). Systems Design.

Checkland advises the use of his methodology with Stage 4 (the conceptual modelling stage) as the basis of systems design in studies where the major difference from a hard systems study is that the systems to be 'engineered' are manifestations of human-activity systems, and thus quantitative model building and assessment becomes problematic. In the case of the Electricity Council Project, if the problem is taken to be the structured one given in the project brief:

> "The problem is (therefore) that of establishing a workable basis for costing accidents, and the allocation of resources to their prevention."
> (Willemstyn 1980)

then the concern of the study becomes that of establishing a workable basis for costing. Thus the main problem concerns design (and implementation).

The crucial stages of the methodology become, in the first instance, (3), defining root definitions of relevant systems, which Checkland redefines for the purposes of this form of study to 'system specification', (4), conceptual model building and (5), comparison stage - which in this case will be models with expectations of proposed systems. (see Figure 22).

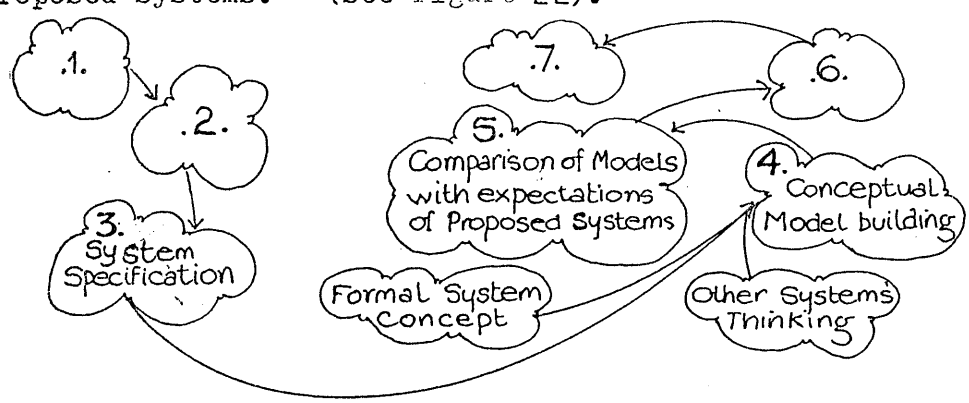


Figure 22. The crucial stages of the Checkland methodology for systems design.

These three stages are now examined below:

Stage 3. System Specification.

This is the ideal specification for the model to be built in Stage 4. There are a wide range of systems which could be 'specified'. This is significant, for Stage 3 is a crux in the methodology and obviously in examining the problem in terms of systems design much will depend on the particular systems chosen to be specified and investigated. A possible system would be:- "A system to derive the costs of accidents annually to the Electricity Supply Industry." This system would draw heavily on two existing systems:

(i) The accident reporting system within the Electricity Supply Industry; and:-

(ii) costing systems in other U.K. industries.

Stage 4. Conceptual Model Building.

Conceptual model building in this instance would involve the formal model building of the accident costing system. Experience (of Checkland(Checkland 1981) and the Open University Systems Group(Naughton 1977)) has shown that it is best to begin by writing down half a dozen or so verbs covering the main activities implied. In this case they might be, for example:-

monitor, define, derive... These verbs are then combined into the model, as described diagramatically in Fig.23.

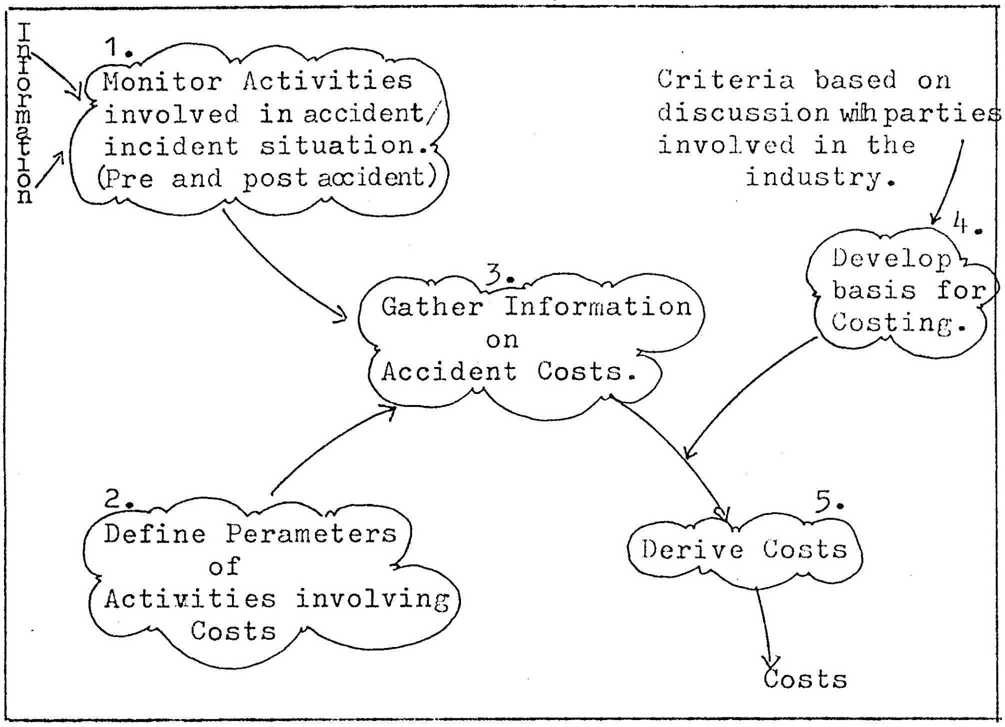


Figure 23. Conceptual Model.

At a more specific level, on iteration, the conceptual model would describe spècific stages in costing. For example: the model would be fed by particular incidents/ accidents and the perameters of the costing exercise. The activities would involve, for instance: "determining the extent of injury to people, damage to plant and the supply of electricity."

Stage 5. Comparison Stage.

In Stage 5 of the methodology the model would be compared with expectations of the proposed systems.

In the case of the Electricity Council Project a proposed costing system had not been formalised. However a useful comparison to be made is that of comparing the conceptual model developed in Stage 4 with the model actually presented to the Electricity Supply Industry.

The conceptual model developed above (see Figure 23.) represents the activities to be performed before the more specific stages involved in 'Activity 5' of the model can be carried out. The model developed for the Electricity Supply Industry (see Figure 15 on Page 48) on the other hand could be used within 'Activity 5' to indicate the areas of potential post-factum costs which may result from an accident.

9. 2. (ii) Action to Improve an Ill Defined Problem Situation.

Most of the studies undertaken by Checkland and the Lancaster Group, using the Checkland methodology, lay within this perspective, and it can be argued that it is forthis type of problem situation that the methodology is most appropriate. On initial examination the Electricity Council Project remit and their expectations of the scope of the issues involved, appears rather narrow to justify applying a methodology such as Checkland's. However, had the methodology been applied it would have raised some interesting questions about the real nature of the problems involved as can be illustrated by the run-through of the initial stages documented overpage.

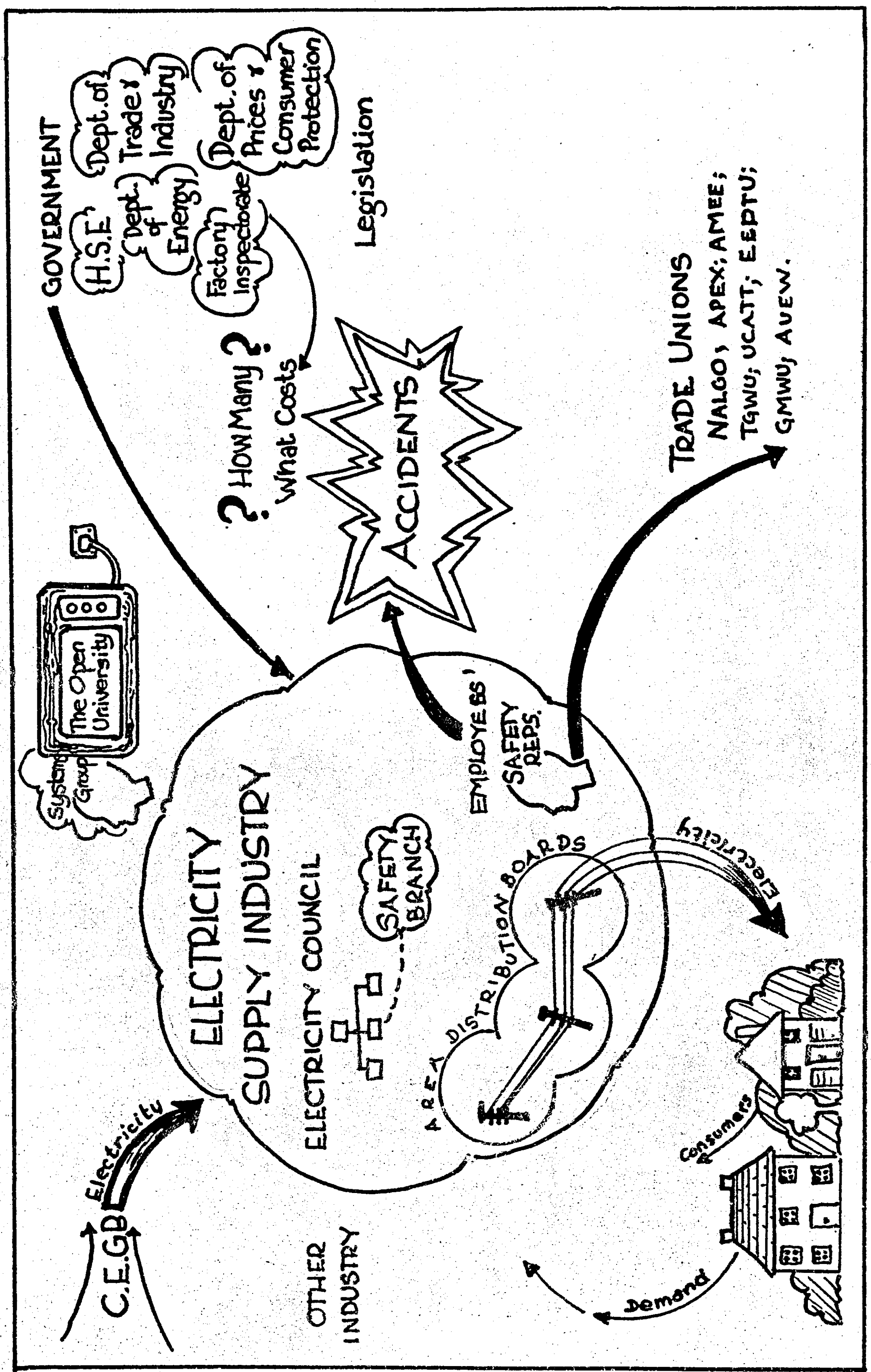


Figure 24. Rich Picture

Use of the initial stages alone would have led to considerable re-thinking of the scope of the problem.

Taking the methodology through its 'logical' chronological order:-

Stages 1 and 2 involve building up as rich a picture as possible of the situation in which the problem is to be found, and expressing it in non-systems terms:
this 'rich picture' is described in Figure 24.

Aspects of the 'rich picture' can be broken down as follows:

1) Environments and Wider Systems.

Industry,
the Electricity Supply Industry,
the Safety Branch of the E.S.I. (see Appendix No. 6)
the demand and the supply of electricity - the relevant market,
Industrial Relations Machinery,
Legislative and administrative functions of government - and relevant legislation (e.g. legislation governing the E.S.I., the Health and Safety at Work Act, Factories Acts, and the Health and Safety Executive...)

2) Structures.

'Production', Supply - distribution, servicing - maintenance and repair, and Sale.
Levels of communication and reporting:

the hierarchical structure of Area Boards, from work-group to Chairman, to the Board of the Electricity Council.

the Advisory Machinery (National Joint Co-ordinating Council); Trade Unions.

the accident reporting structure (statutory and non-statutory). (For more detail see Appendix No. 3.)

3) Processes.

Consumers' demand and Industry's supply - remits to produce, supply service.

Monitoring of accidents by Safety Branch of the Electricity Council.

Safety Representatives, the Health and Safety Executive, and the Department of Energy.

Stage 3: Relevant Systems and Root Definitions.

As stated above, Stage 3 is a crux of the methodology and thus much depends on the relevant systems chosen.

On initial examination in the case of the Electricity Supply Industry the relevant systems pertinent to the problem would appear to be:

1) the safety system within the industry
2) the accident producing system (within the E.S.I.)
3) the system of communication and power within the the Electricity Supply Industry with reference to the Safety function.
4) a system to elevate the status of safety within the Electricity Supply Industry.

According to Checkland (1981) a root definition will be a meaningful description of the relevant system according to a particular Weltanschuung (or view of the world).
On a first run through the methodology the root definition derived will be issue based, rather than primary task, the distinction here is between high-level more contentious issues or systems where differing perceptions are likely to be involved, and lower-level tasks or functions which tend to be less contentious; thus a root definition for system number 4 above which appears to lend itself to interesting initial investigation might be:

> "A system to elevate the status of the Safety Branch within the Electricity Supply Industry by generating awareness of the financial and social contribution implicit in the Safety function for the Industry's operations."

Checkland describes his methodology as a learning process or system, and in dealing with problems such as those thrown up by the Electricity Council Project it certainly helps to provide useful insights into apparently straightforward issues, and leads to a questioning of previously accepted statements and value judgements.

Chapter Ten. Outline Attempt at Applying the de Neufville and Stafford Methodology to the Project.

10. 1. Description of the Methodology.

The de Neufville and Stafford methodology is what is known as a 'hard systems' methodology. It has its roots in the 'rigorous scientific method' and thus evaluation techniques largely rest on quantitative analysis.

The methodology, as detailed by de Neufville and Stafford in 'Systems Analysis for Engineers and Managers' (1971), has five basic elements or stages. These are:-

1) the definition of objectives
2) the formulation of measures of effectiveness
3) the generation of alternatives
4) the evaluation of the alternatives
5) selection

The stages are linked together with a feedback loop to provide a dynamic modelling process, as described in Figure 25.

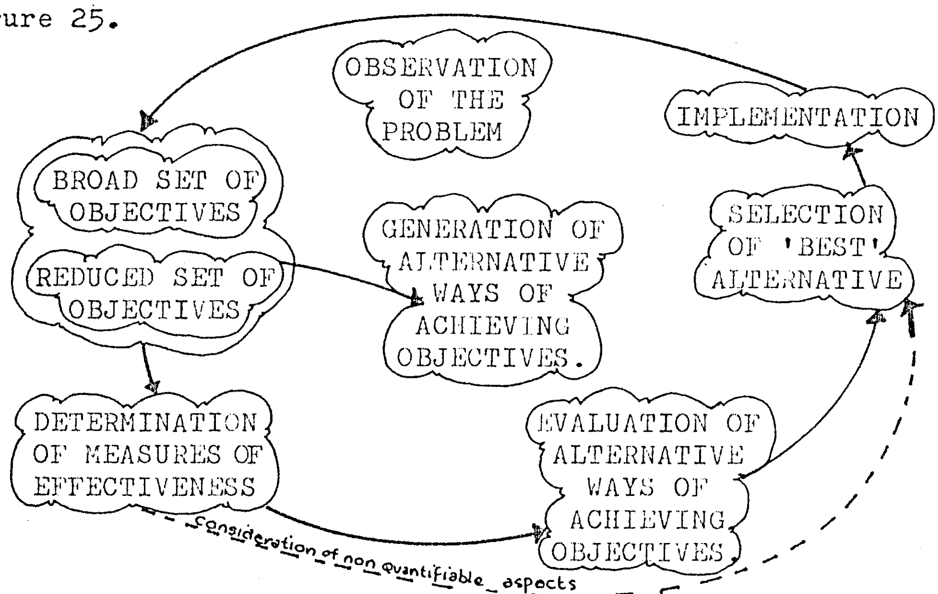


Figure 25. The de Neufville & Stafford Methodology.

10. 2. Applying the Methodology to the Electricity Council Project.

Working as an analyst, slightly removed from the problem situation in contrast to the Checkland methodology where the methodology can be seen more as a debate with the actors involved, the initial stages of the de Neufville and Stafford methodology have been applied to the Electricity Council Project in a preliminary exploratory way. The author has drawn on the data collected whilst on field research and this includes behavioural observations and conclusions drawn as well as the hard statistical data. From observation of the problem objectives can be derived:

Stage 1. Definition of Objectives.

Objectives are defined widely initially to arrive at broader system objectives from which a smaller set which is more pertinent to the problem can be drawn. At this stage a particular motive for staying with and being interested in the study is also identified.

Objectives of the wider system within which the problem is to be found

A. Societal
1. To conserve energy resources
2. To minimise the cost of electricity to consumers
3. To improve and enlarge upon the body of knowledge about safety hazards
4. To increase expenditure on safety
5. To minimise expenditure on safety by Govt. Dept.s.
6. To minimise expenditure on safety by other agencies.

B. Electricity Supply Industry Objectives

1. To provide an effective service; that is, to distribute and maintain an efficient supply of electricity to consumers, at minimum cost and with minimum danger to life and limb.
2. To reduce the hazards associated with the Electricity Supply Industry's work.
3. To minimise the number of accidents occuring within and outside outside the Industry as a result of its operations.
4. To minimise expenditure by the Industry.
5. To maintain the cost of electricity to consumers at a competitive price.
6. To promote the sale of electricity.

C. Safety Branch Objectives

1. To reduce the hazards associated with the Electricity Supply Industry's work.
2. To reduce the hazards associated with low and medium voltage supply work.
3. To reduce the number of accidents occuring within and outside the Industry as a result of its operations.
4. To reduce the number of accidents involving low and medium voltage supply work.
5. To keep the Safety Branch's expenditure within budget constraints.
6. To increase expenditure on safety.
7. To enlarge the Safety Branch of the Electricity Supply Industry.
8. To give effective advice to the Electricity Council, the Area Boards and CEGB on all aspects of safety and accident prevention, and on acceptable standards of occupational health and hygiene (excluding Nuclear accidents)
9. To facilitate constructive activity at National and District level of the Joint Consultative Machinery on safety issues.
10. To improve the status of the Safety Branch, both within and outside the Industry.
11. To create a single safety organisation within the Electricity Supply Industry.
12. To improve and enlarge upon the body of knowledge about safety and hazards.

Particular Motive for Study

To reduce hazards and accidents associated with low and medium voltage supply work in the Electricity Supply Industry; and to elevate the status of the Safety Branch.

Reduced Set of Objectives

(Numbers in brackets refer to the wider set of objectives.)

1. To reduce hazards and accidents associated with low and medium voltage supply work within the Electricity Supply Industry. (B2, C2, C4.)
2. To give effective advice to the Electricity Council, the Area Boards, and the CEGB on all aspects of safety and accident prevention and on acceptable standards of occupational health and hygiene, (excluding Nuclear accidents.) (C8.)
3. To promote safety with a view to reducing hazards and preventing accidents. (C6, C7, C8, C12.)
4. To facilitate constructive activity at National and District level of the Joint Consultative Machinery, on safety issues. (C9.)
5. To create a single safety organisation, centrally controlled, with independent authority and adequate resources, to replace the present fragmented system. (C10, C11, C6, C7.)
6. To elevate the subject of safety to the status of an academic discipline incorporating a 'total' broad-based approach to safety, and simultaneously raising the bargaining position of the Safety Branch itself. (C10, C11, C12.)

Stage 2: The Function of Measures of Effectiveness.

These are measures of effectiveness or performance which reflect the objectives defined in Stage 1. The measures generated should all be recordable, however, in the case of the Electricity Council Project some date required would not be readily available.

A.	Measures of Effectiveness Reflecting Objectives Numbers 1,2,3, from the Reduced Set.
A.1.	The change in the total number of lost-time accidents per 1,000 man-hours worked for a given year.
A.2.	The change in the number of lost-time accidents per 1,000 man-hours worked associated with low and medium voltage supply work, in a given year.
A.3.	The change in the probability of having an accident whilst working on low and medium voltage supply tasks in a given year.
A.4.	The change in the number of unsafe incidents occuring in a given year.
A.5.	The change in the number of man-hours lost due to sickness and accidents in a given year.
A.6.	The change in the cost of accidents in a given year.
A.7.	The change in the cost of accidents for specific named tasks performed, in a given year.
A.8.	The change in the number of requests for safety information by the Electricity Council/Area Boards/CEGB, in a given year.
A.9.	The number of repeat requests for safety information in a given year.

B. Measure of Effectiveness Reflecting Objective Number 4 of the reduced set.

B.1. The number of initiatives on safety arising out of joint activity in a given year.

C. Measures of Effectiveness Reflecting Objectives Numbers 5 and 6 of the reduced set.

C.1. The size of the Safety Branch's budget, in a given year.
C.2. The peoportion of the budget requested given, for a given year
C.3. The number of requested interactions with outside agencies and governmental departments in a given year.
C.4. The annual change in staff numbers in the Safety Branch.
C.5. The proportion of safety-employees within the Electricity Supply Industry who report directly to the Safety Branch, as opposed to those who report within the Area Board hierarchy to the Engineering Manager.

Stage 3. The Generation of Alternatives.

These alternatives are alternative ways of achieving the reduced set of objectives from Stage 1.

Alternatives.

1. Increase the number of safety-staff who report directly to the Safety Branch.
2. Conduct a wide-ranging safety publicity campaign aimed specifically at low and medium voltage supply work.
3. Make it compulsory for all low and medium voltage supply work at present carried out 'live', to be performed with the system made dead.
4. Make the whole system high voltage.
5. Promote safety as the prime interest of the Industry.
6. Introduce a 'no-accident' payment system.
7. Develop and utilise reliable and effective equipment in conjunction with a safe procedure for working on underground cables, in order to:-
   (i) determine or confirm the exact position and voltage of cables, and:
   (ii) prove that a cable has been made dead at the point of work.
8. Do nothing.

Stage 4. Evaluation.

For the purposes of the evaluation below only the quantifiable aspects have been used. This is obviously not a full and detailed evaluation, but a useful short-cut to home in on particular alternatives that may prove to be practicable and worthy of further exploration and elaboration. At this stage in a real study, an interim report with this form of evaluation could be sent back to the client (here, the Electricity Council) for comment and further consideration. The next step would be to compute the content of each cell of a shorthand matrix derived from the one below. Non-quantifiable aspects would then be brought onto the final evaluation stage.

The notation used in the matrix (Figure 26) below, corresponds to a '++' through 'blank' to '--' scale of 'very beneficial' to 'very non-beneficial' results.

Measures of Effectiveness

Alternatives

	A1	A2	A3	A4	A5	A6	A7	A8	A9	B1	C1	C2	C3	C4	C5
1.						+	+				+			+	+
2.	+	+	+	+	+	+		+	+						
3.	+	++	++	+	+	+									
4.	?+	+	++	?+	+	+	?								
5.	++	++	++	++	++	++	++	+	+	+	+	+	+	+	+
6.	+	+	+	+	+	+	?				?				
7.	+	++	++	+	+	+	?+								
8.															

Figure 26. Evaluation Matrix.

The de Neufville and Stafford methodology provided a different approach to the Electricity Council Project to that arrived at using the straightforward economic approach adopted and the Checkland methodology. The objectives defined at the outset laid the foundations for a wider-ranging and more diverse study than the actual course under taken for the Electricity Council. However, there are problems inherent in using the de Neufville and Stafford methodology which necessarily conditioned the shape and direction of the study and its results. The methodology as stated earlier, has its roots in the scientific engineering method and thus tends to rely almost exclusively on quantitative evaluation and justification. Further difficulties are discussed in the following chapter.

Chapter Eleven. The Development of the Hard Systems Method.

11. 1. The Development of the Hard Systems Method.

This thesis has been written not only to satisfy the needs of the Electricity Council Safety Branch in terms of the development of a model enabling the costing of industrial accidents, but also to examine the role and impact of systems theory on the real world problem posed by the Electricity Council Project.
The systems movement lacks maturity and Vickers argues, "a professional focus" because of the absence of a strong link between systems theory and systems practice. As an interdisciplinary area the progress, and development, and testing of general ideas in application is inevitably slow but essential.

In Section III a hard methodology (that of de Neufville and Stafford) and a softer system methodology (Checkland's) were used as frameworks for re-examining the Electricity Council Project. Both methodologies proved illuminating in their own way. Although Checkland developed his soft systems methodology as a result of frustration experienced by attempts at using hard systems methodologies in what he saw to be 'soft' situations, there are aspects of a harder method which seem to be appropriate in these so-called soft situations. Checkland's methodology provides useful and

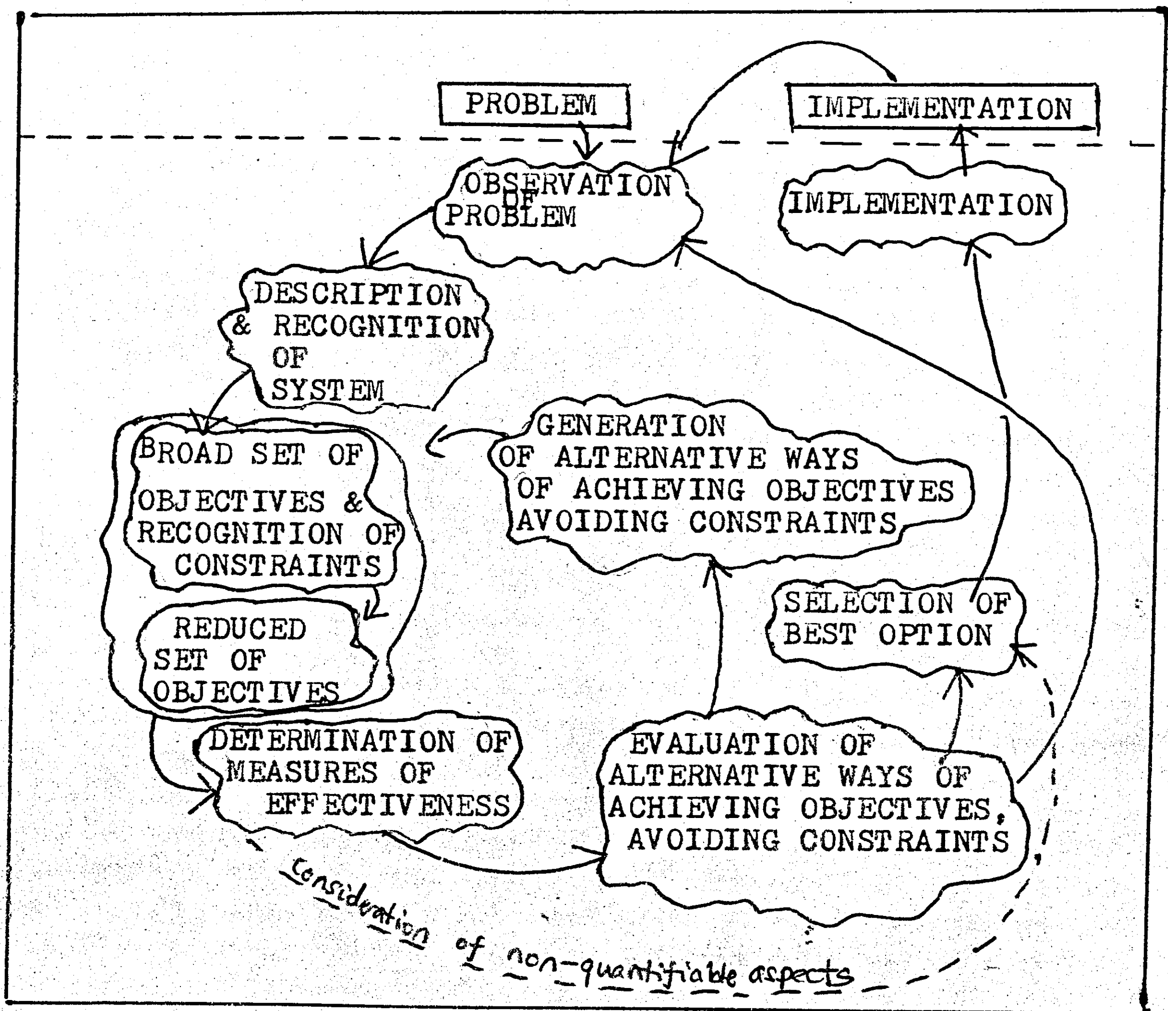


Figure 27 The Hard Systems Method

fluid guidelines in the initial stages for examining and understanding the situation in which the problem is to be found, and aspects of the problem itself which are proving pertinent. And, equally, the harder methodologies - in particular, that of de Neufville and Stafford, have later stages which are appropriate for rigorous examination of alternatives or options for re-evaluating the problem situation under new strategies. A natural development of this line of thought was to evolve a new methodology, which might embrace both the hard and soft aspects of human activity systems and their problems. Thus, together with the two other members of the Open University Systems Group experiencing similar difficulties with using the existing methodologies in organisational settings, the author developed the 'Hard Systems Method'.

11. 2. The Method Described Full Description: Appendix 5, page 127

The basic stages of the Hard Systems Method are:-

1) The recognition and description of the system of interest to the problem.
2) The definition of objective (associated with the problem, of the system and its environment), and constraints.
3) Formulation of measures for determining effectiveness
4) The generation of options.
5) The evaluation of options.
6) Selection.
& 7) Implementation which has two stages: conceptual and actual.

The method is essentially iterative and has four major phases of iteration:

The first is concerned with describing the system and defining objectives and constraints; the second with eval-

uating and modelling selected options; the third with investigating the implications of implementing a selected option; and the fourth with actually implementing a selected option and thereafter monitoring.
The broadening of the early stages allows consideration of the system, the problem and the nature of the objectives and constraints. And the recognition of constraints which may in reality be conflicting objectives forces consideration of aspects of the problem which frequently are non-quantifiable. The iterative phrases determine consideration and re-consideration of the effects of policies. All these factors contribute to a softening and broadening of emphasis.

The Method is described diagramatically in Figure 27; and reproduced as the original draft of the Hard Systems Method in Appendix 5.

The Hard Systems Method is currently being rewritten and will provide a significant imput for the new Open University Systems course - T301, 'Complexity, management and change: applying a systems approach'. It is also hoped that the methodology will prove an important stage in the development of systems thought - acting to some extent as a bridge between what has formerly been considered hard and soft aspects of human-activity problems, although remaining as essentially a Hard Method.

Chapter 12. Concluding Remarks.

12. 1. The Safety Function in the Electricity Supply Industry.

The Electricity Supply Industry is typical of many old and large U.K industries in that its functions and organisation are of a complex nature. This is due in part to its historical growth and development as well as to its multiplicity of physical sites. This obviously has implications for all of the Industry's operations and in the sphere of safety leads to problems with co-ordination, coherence and effectiveness.

The Safety Branch manifests other problems of which the request for this research is symptomatic. From early discussions with members of the Safety Branch it was obvious that they felt a better Safety function could be achieved, in terms of intervening more effectively at various levels in the Industry. The federated nature of the Industry means that the safety function is split, taking place on two different levels - (i) within the Area Boards where the work gets done and the accidents happen, safety is organised internally and through Trade Union Representatives; and (ii) directly from the Safety Branch by means of Regional Safety Officers who intervene less directly in the day to day activities, but form the link in the two-way communication chain between the workers at

Area Board level and the Safety Branch itself. Not only are the levels of intervention problematic, but the Branch is itself in a position of being a part of one of the Industry's functions, the Engineering function; this position is historical but also illustrates the role that safety plays in industry even today. In order that the safety function should become and be seen to become, equally or more important as the other activities that are essential for guaranteed production, it should be awarded as strong a position in the Industry's bargaining hierarchy.

12. 2. Further Conclusions on Costing Accidents.

Conclusions about the validity and pitfalls involved in costing accidents from a narrow perspective have been made in <u>8. 2.</u> above.
To these, the final comments below can be added:-

The request by the Electricity Council Safety Branch for a means of costing their industrial accidents was obviously indicative of many facts about the Branch which have been illustrated in the course of the thesis. But the Safety Branch also wanted a means of working out what exactly accidents in general and individual classes of accidents were costing the Industry in terms of money. Essentially they were requesting an alternative measure by which they could assess their effectiveness and a measure which would enable them to evaluate the activiteis involved in the Industry's operations which had 'high-cost' implications for safety.

Although money appears to be a good base for costing accidents as it assists ready comparison both within and between industries, it says nothing about the factors involved in accidents that are not easily or readily quantified in these terms.

To make statistics significative and to help make safety a more integral part of industries' essential processes, other bases for costing accidents could be profitably explored. A further study could usefully examine this area.

APPENDIX NUMBER 1.

PROJECT-BRIEF.

Project Title

Costs of accidents in the Area Electricity Boards in England and Wales with particular reference to low and medium voltage electrical accidents.

Statement of Problem

The Electricity Council have statistical evidence to suggest that hazards involving injuries to people and damage to plant are associated with work involving low and medium voltage supplies in the Area Boards.

This raises the possibility that there may be a need for additional resources to investigate and reduce these hazards. However, it is not clear at the moment what scale of resources might be needed. It is felt that an estimate of the annual cost to the Electricity Supply Industry of incidents in this category would be of great help in discussing such resource issues. The problem is therefore that of establishing a workable basis for costing accidents and the allocation of resources to their prevention.

It is recognised that such a costing itself conceals other issues, such as:

1) The general conceptual basis on which such a costing should be made is far from clear, so that the development of an acceptable costing rationale would have to find some resolution of issues such as the costing of both direct and

indirect costs, where direct costs are those which cannot be readily "accounted", including certain consequential costs. It is hoped to develop a model for assessing both types of costs as a basis for costing accidents generally in the Electricity Supply Industry.

Another issue is the definining of criteria for accidents and incidents.

2) At a more specific level, much of the data needed for any form of costing is relatively inaccessible under the Industry's present accident information system. Because of the Health and Safety at Work Act, and the resulting pressures on the supply industry from the Health and Safety Executive and other bodies, and the proposed revision of the accident reporting procedures for the Health and Safety Executive and the Department of Energy, and because it is information needed by management in the industry for good business accounting, there would be a long term benefit to the industry if the costing exercise were to suggest what data should be collected routinely for any incident.

Other issues beyond these will no doubt emerge as the study progresses.

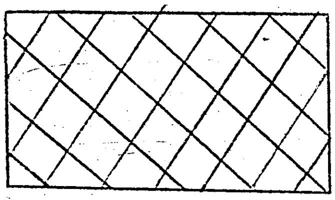
It is important that the project should be allowed to start as a fairly broad-based enquiry that converges on a precise project definition relatively late on, perhaps after some months. This is to ensure that we do not embark on a project that seems to be clear-cut initially but may turn out to be unfeasible or of less value to the council than it at first appears. However, it is to be clearly understood that the project will remain strictly within the costing and resource area.

APPENDIX NUMBER 2.

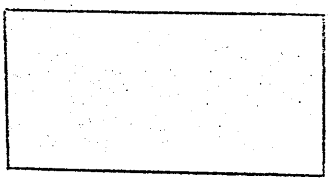
SUMMARY OF CASE HISTORIES OF ACTUAL ACCIDENTS STUDIED.

Figure 28.
KEY-PAGE

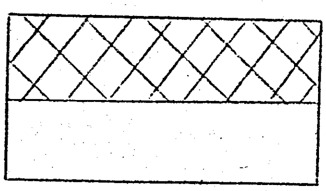
This is the 'key' to the notation used in the diagrammatic Case Histories



Shaded boxes are descriptive of the various stages in the accident-sequence



'Plain' boxes describe in Units of cost, the type of Costs involved.



(Combined) boxes, containing both shaded and plain areas describe an event in the Accident-consequence sequence and the associated cost.

'UNIT COSTING'

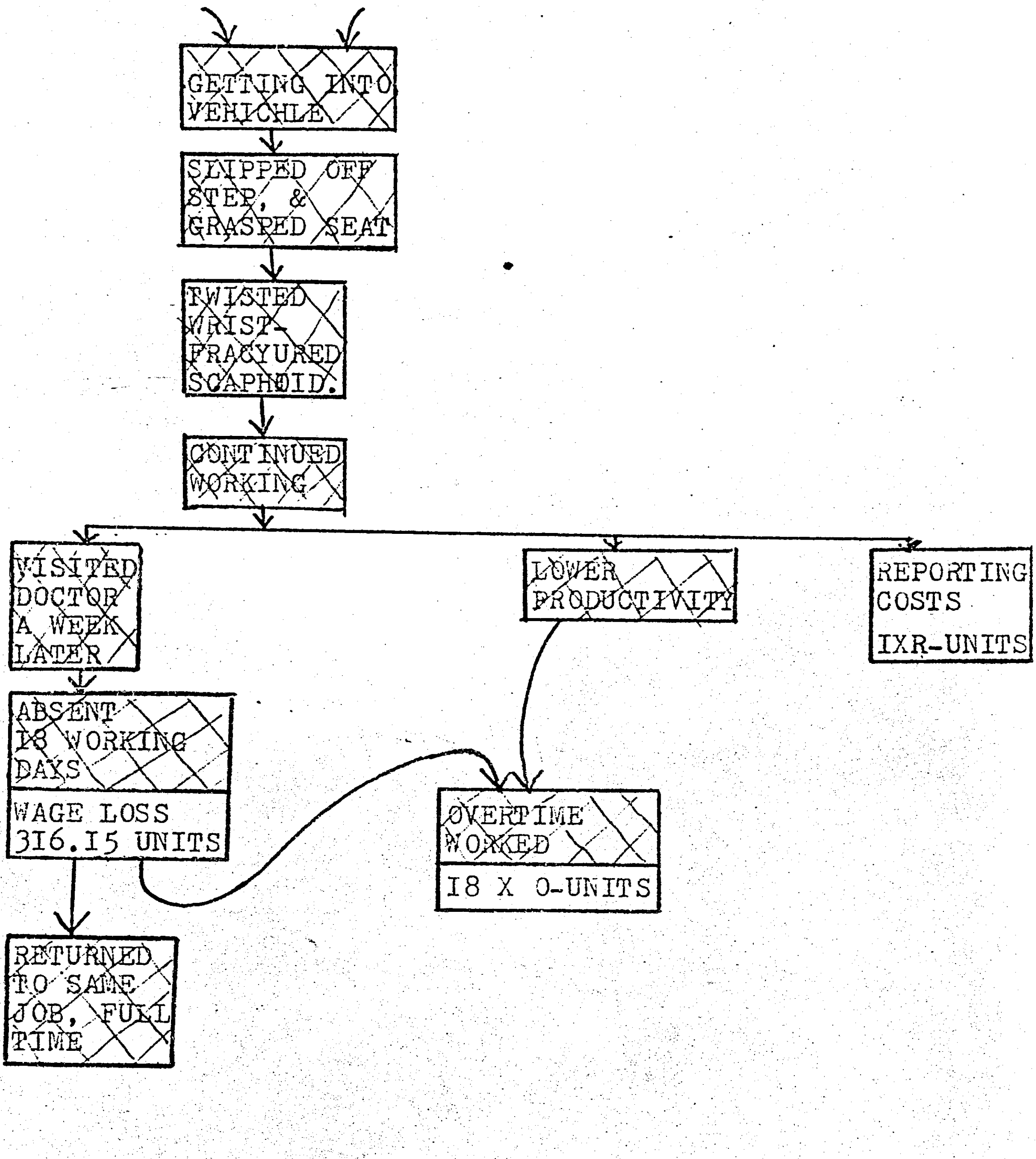
All costs have been broken down into 'Units' of actual costs. This enables all categories to be identified without quantifying them in cash terms at every stage. It means that specific categories that may be difficult to quantify accurately do not have to be ignored.

Using this approach some tentative conclusions concerning actual costs have been made.

Figure 29

EASTERN ELECTRICITY BOARD. NORWICH DISTRICT. CASE HISTORIES.

LINESMAN ACCIDENT CLASSIFICATION: 'PERSONS FALLING'



TOTAL COSTS: 3I6.I5 UNITS, PLUS I8 O-UNITS, PLUS I X R-UNITS.

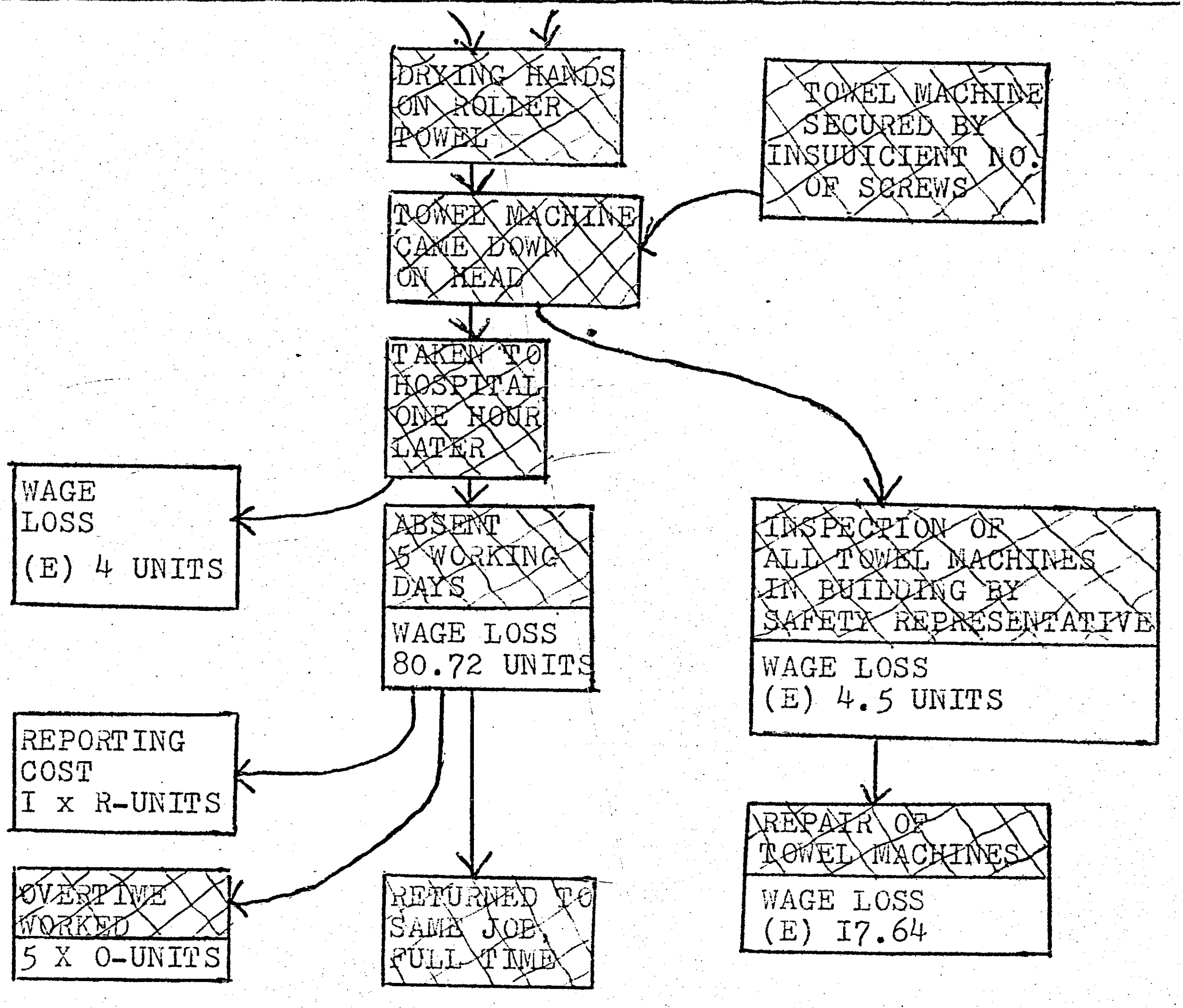
PLUS 'OTHER NON-E.S.I. COSTS': Costs to the individual of pain & sufferin
Costs to society of medical treatment & DHSS payment.

FOR KEY TO DIAGRAM AND 'UNIT' COSTING REFER TO KEY-PAGE.

Figure 30

EASTERN ELECTRICITY BOARD. NORWICH DISTRICT. CASE HISTORIES.

ELECTRICIAN('S MATE). ACCIDENT CLASSIFICATION: OBJECTS FALLING



TOTAL COSTS: I06.86 UNITS, PLUS I xR-UNITS, PLUS 5 x O-UNITS.

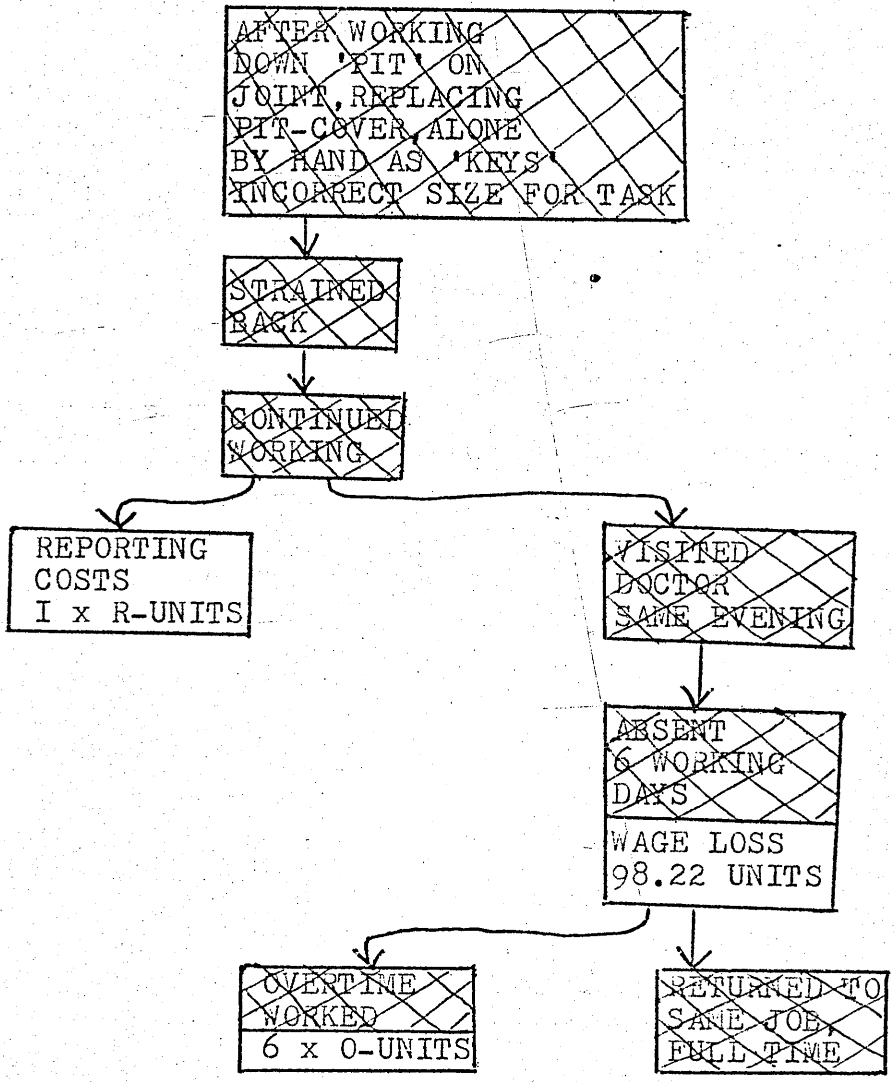
PLUS OTHER 'NON-E.S.I' COSTS: Costs to individual of pain & suffering, Costs to society of medical treatment & DHSS payment.

FOR KEY TO DIAGRAM AND 'UNIT' COSTING REFER TO KEY-PAGE.

Figure 31

LONDON ELECTRICITY BOARD. WANDLE DISTRICT. CASE HISTORIES.

JOINTER ACCIDENT CLASSIFICATION:HANDLING OBJECTS



TOTAL COSTS: 98.22 UNITS, PLUS 1 x R-UNITS, PLUS 6 O-UNITS.

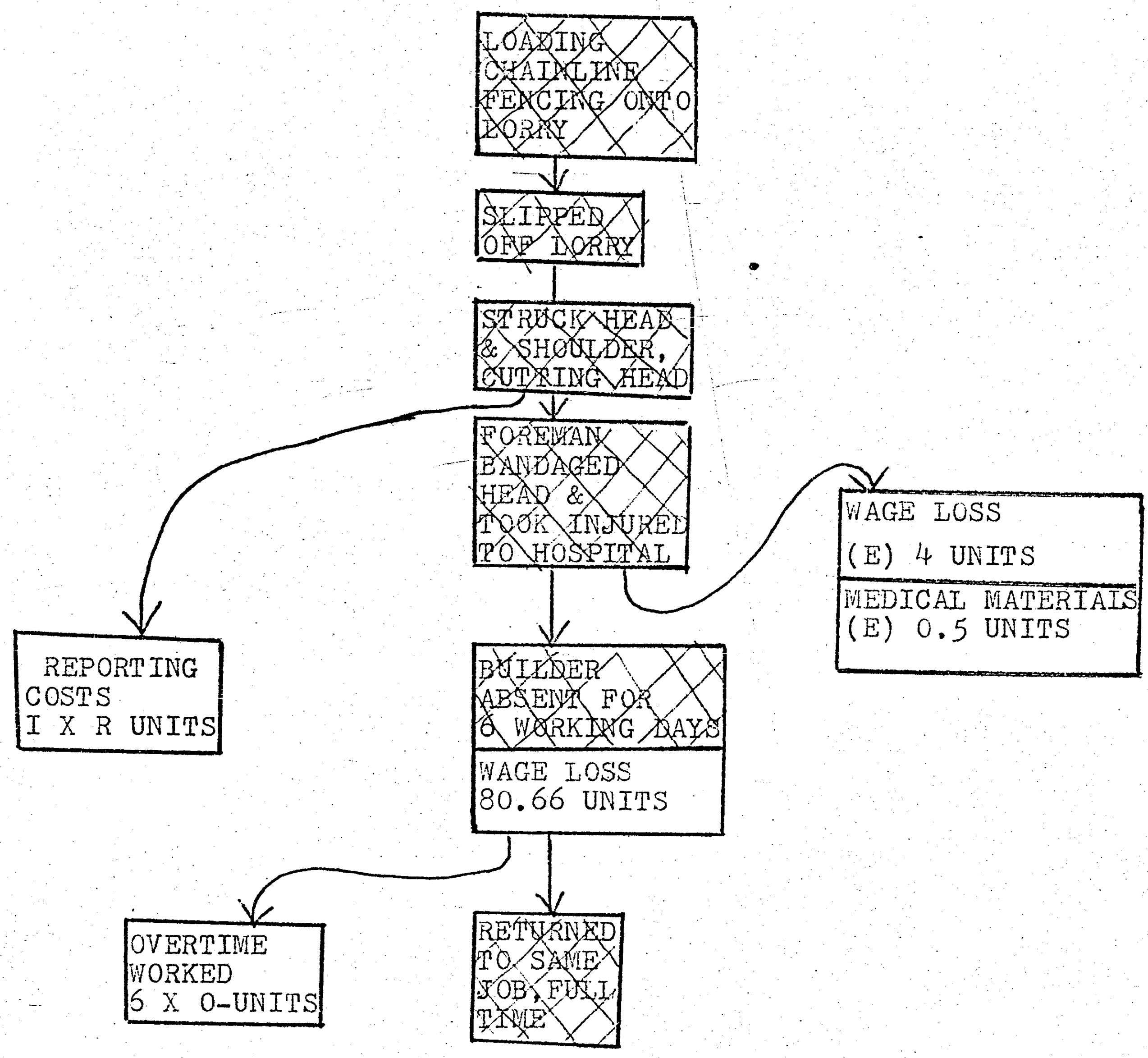
PLUS OTHER 'NON-E.S.I.' COSTS: Costs to the individual of pain & suffering
Costs to society of medical treatment & DHSS payment.

FOR KEY TO DIAGRAM AND 'UNIT' COSTING REFER TO KEY-PAGE

Figure 32

EASTERN ELECTRICITY BOARD. NORWICH DISTRICT. CASE HISTORIES.

BUILDER ACCIDENT CLASSIFICATION: PERSONS FALLING



TOTAL COSTS: 84.66 UNITS, PLUS 0.5 UNITS, PLUS 6 X O-UNITS, PLUS I X R-UNITS

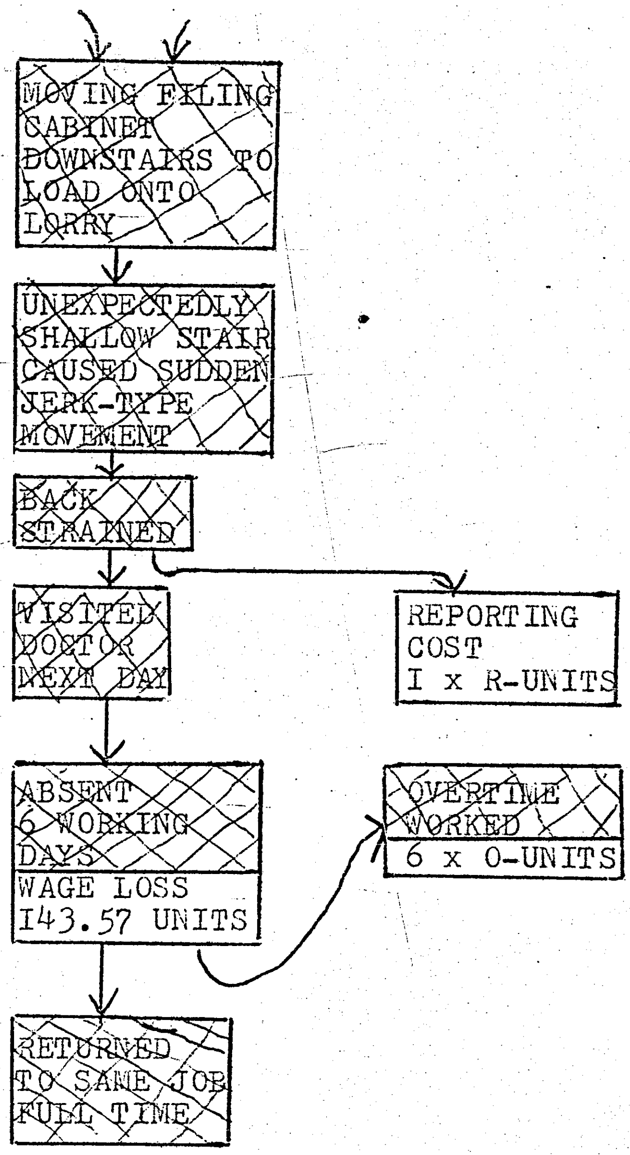
PLUS 'OTHER NON-E.S.I. COSTS': Costs to the individual of pain & suffering. Costs to society of medical treatment & DHSS payment.

FOR KEY TO DIAGRAM AND 'UNIT' COSTING REFER TO KEY-PAGE.

Figure 33

EASTERN ELECTRICITY BOARD. NORWICH DISTRICT. CASE HISTORIES

ELECTRICIAN. ACCIDENT CLASSIFICATION:HANDLING OBJECTS



TOTAL COSTS: I43.57 UNITS, PLUS I x R-UNITS, PLUS 6 x O-UNITS.

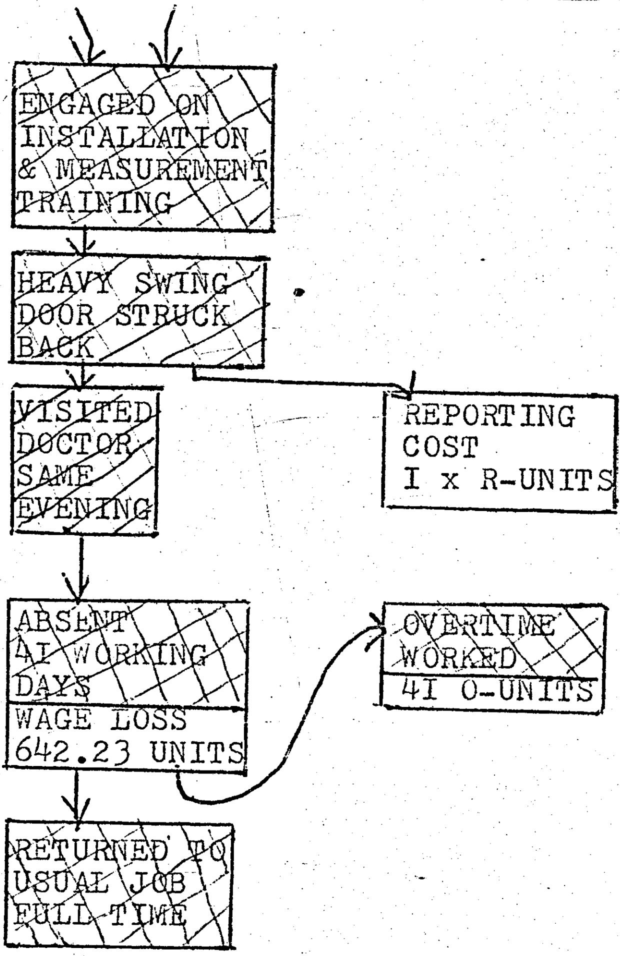
PLUS OTHER 'NON -E.S.I.' COSTS: Costs to individual of pain & suffering, Costs to society of medical service & DHSS payment.

FOR KEY TO DIAGRAM AND 'UNIT' COSTING REFER TO KEY-PAGE.

Figure 34

EASTERN ELECTRICITY BOARD NORWICH DISTRICT. CASE HISTORIES

ELECTRICIAN ACCIDENT CLASSIFICATION: STEPPING ON OR STRIKIN AGAINST OBJECTS.



TOTAL COSTS: 642.23 UNITS, PLUS I x R-UNITS, PLUS 41 O-UNITS

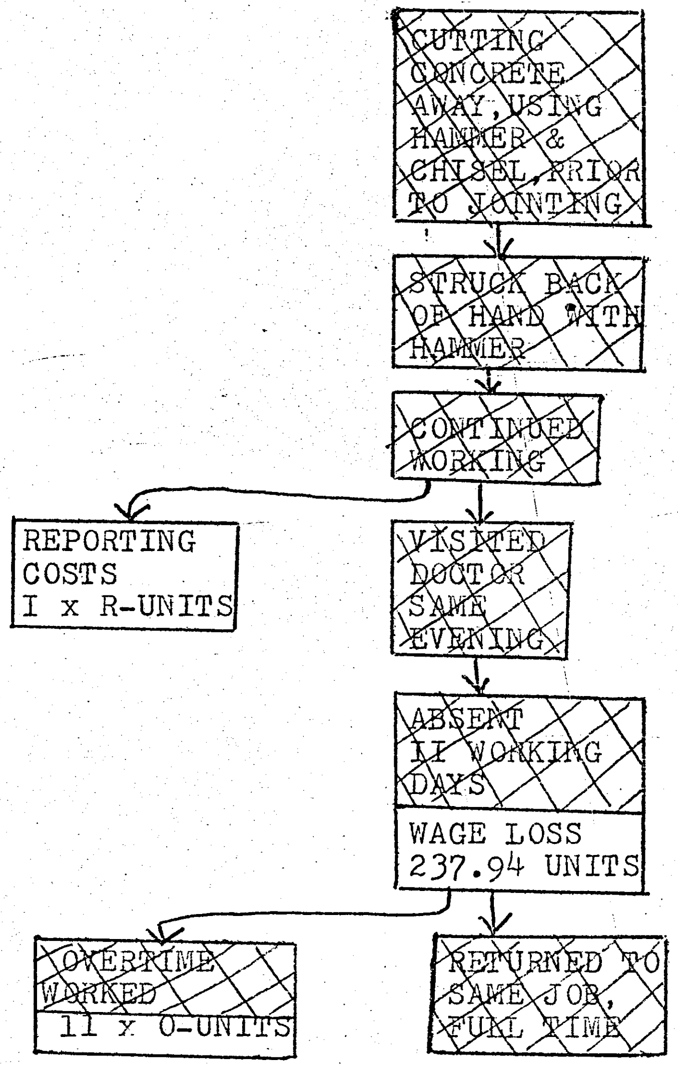
PLUS OTHER 'NON-E.S.I.' COSTS: Costs of pain & suffering for individual, Costs of medical treatment & DHSS payment for society.

FOR KEY TO DIAGRAM AND 'UNIT' COSTING REFER TO KEY-PAGE.

Figure 35

L'NDON ELECTRICITY BOARD. WANDLE DISTRICT. CASE HISTORIES.

JOINTER ACCIDENT CLASSIFICATION: USE OF HAND TOOLS



TOTAL COSTS: 237.94 UNITS, PLUS 1 x R-UNITS, PLUS 11 O-UNITS.

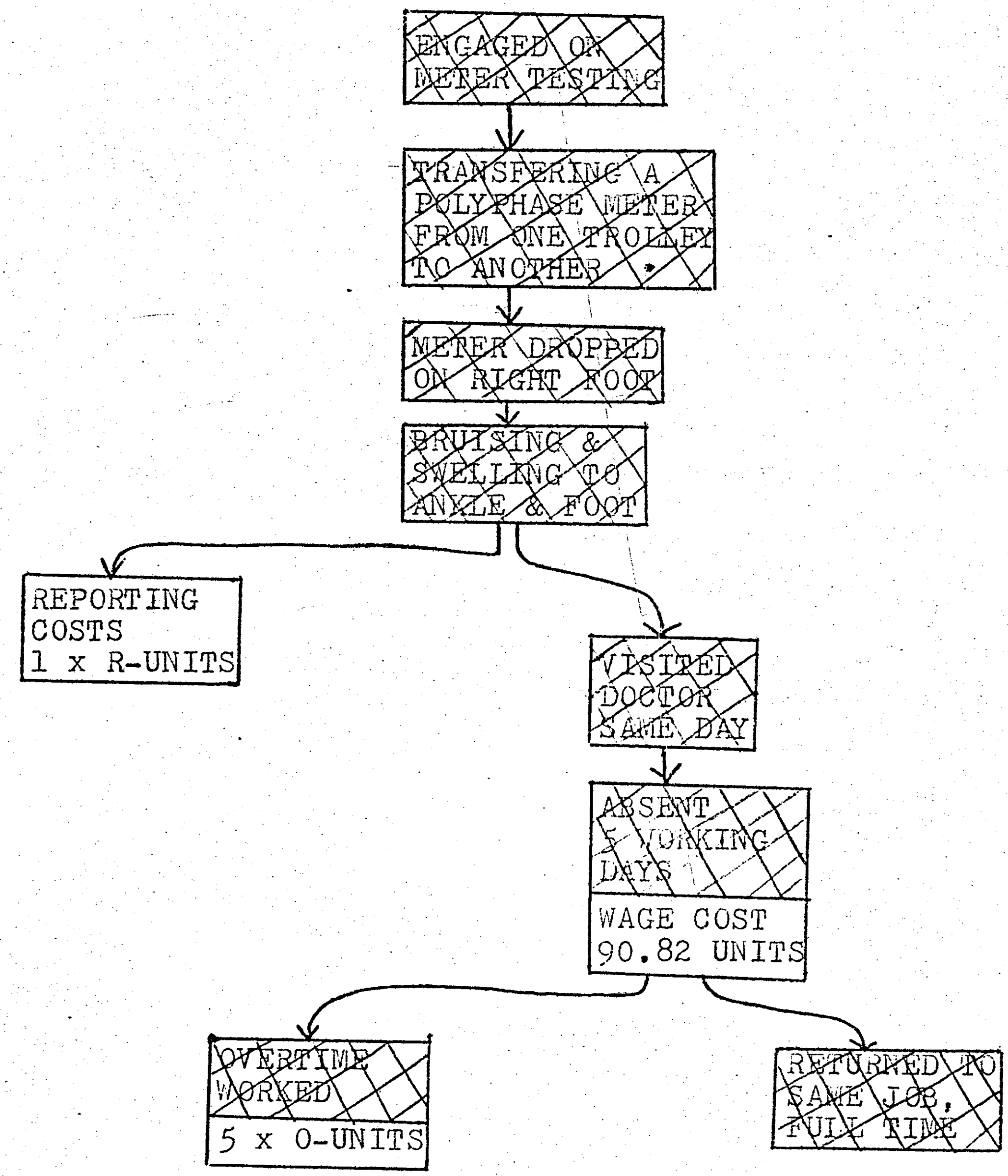
PLUS OTHER 'NON-E.S.I.' COSTS: Costs to the individual of pain & sufferin
Costs to society of medical treatment & DHSS payment.

FOR KEY TO DIAGRAM AND 'UNIT' COSTING REFER TO KEY-PAGE

Figure 36

EASTERN ELECTRICITY BOARD. NORWICH DISTRICT. CASE HISTORIES.

METER MECHANICIAN ACCIDENT CLASSIFICATION: HANDLING OBJECTS



TOTAL COSTS: 90.82 UNITS, PLUS 1 x R-UNITS, PLUS 5 O-UNITS.

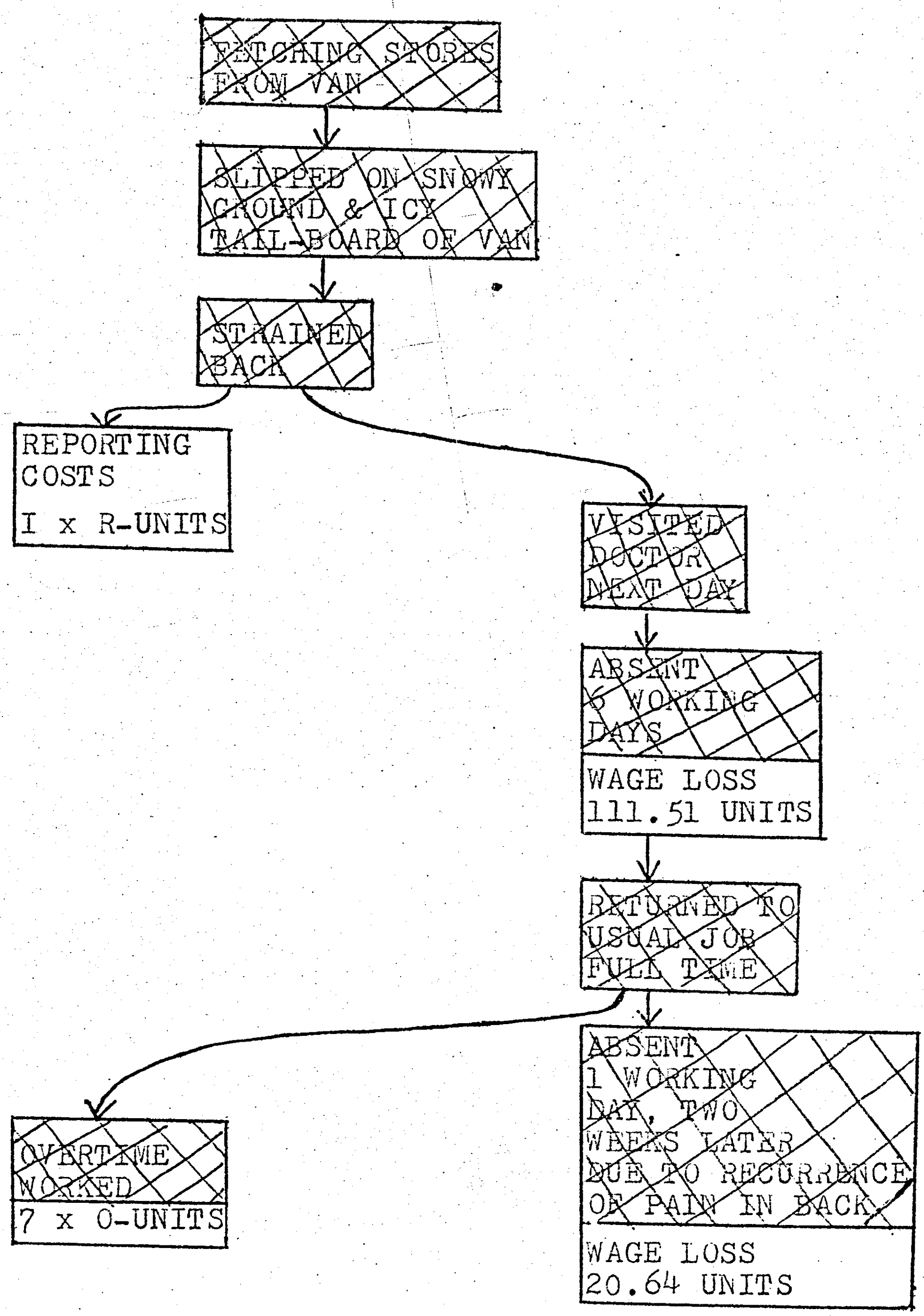
PLUS OTHER 'NON-E.S.I.' COSTS: Costs to the individual of pain & suffering
Costs to society of medical treatment & DHSS payment.

FOR KEY TO DIAGRAM AND 'UNIT' COSTING REFER TO KEY-PAGE

Figure 37

EASTERN ELECTRICITY BOARD. NORWICH DISTRICT. CASE HISTORIES.

LINESMAN ACCIDENT CLASSIFICATION: PERSONS FALLING



TOTAL COSTS: 132.15 UNITS, PLUS 1 x R-UNITS, PLUS 7 O-UNITS.

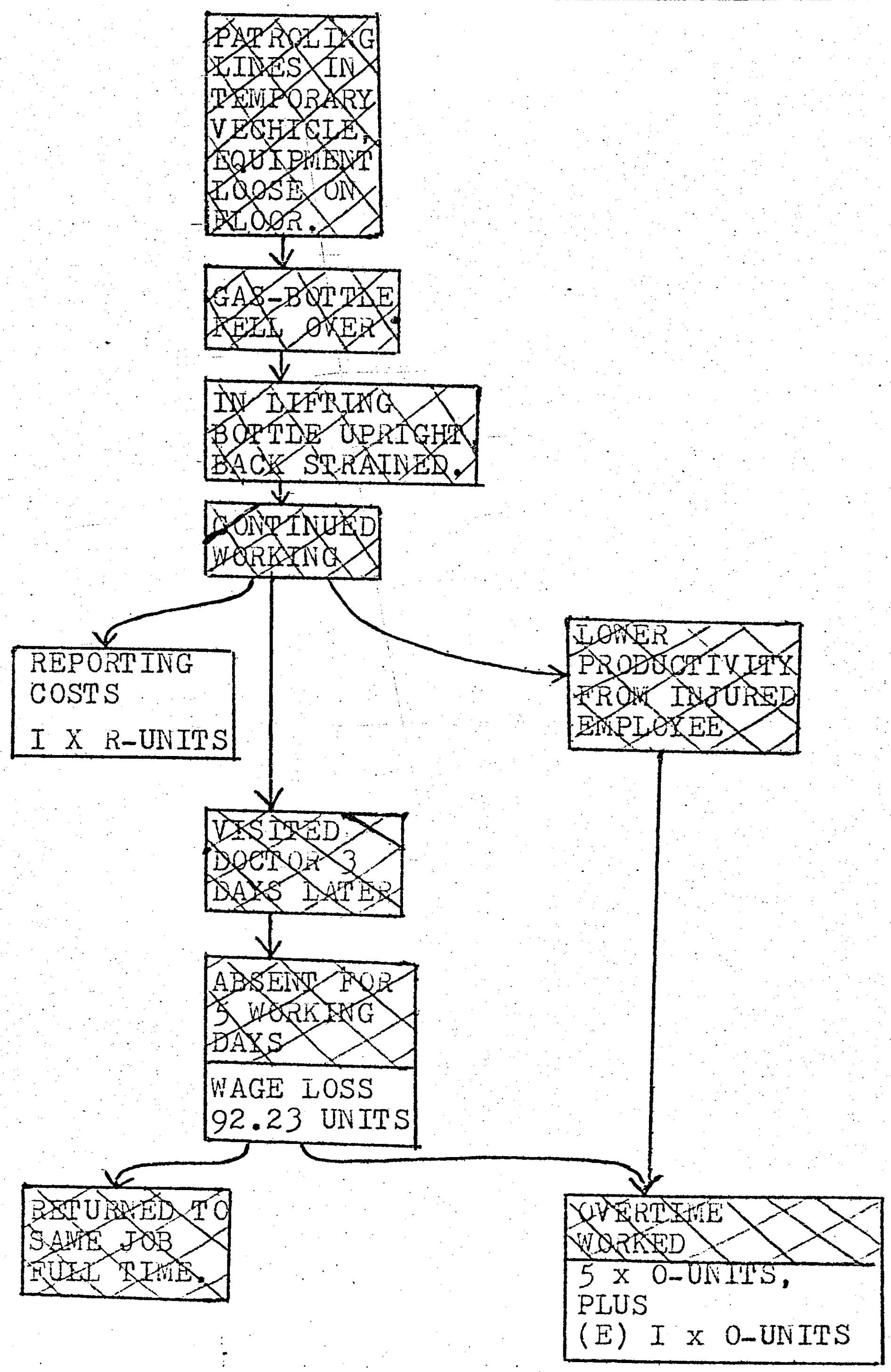
PLUS OTHER 'NON-E.S.I.' COSTS: Costs of pain & suffering for individual, Costs to society of medical treatment & DHSS payment.

FOR KEY TO DIAGRAM AND 'UNIT' COSTING REFER TO KEY-PAGE

Figure 38

EASTERN ELECTRICITY BOARD.. NORWICH DISTRICT. CASE HISTORIES.

LINESMAN ACCIDENT CLASSIFICATION: HANDLING OBJECTS



TOTAL COSTS: 92.23 UNITS, PLUS I x R-UNITS, PLUS 6 x O-UNITS.

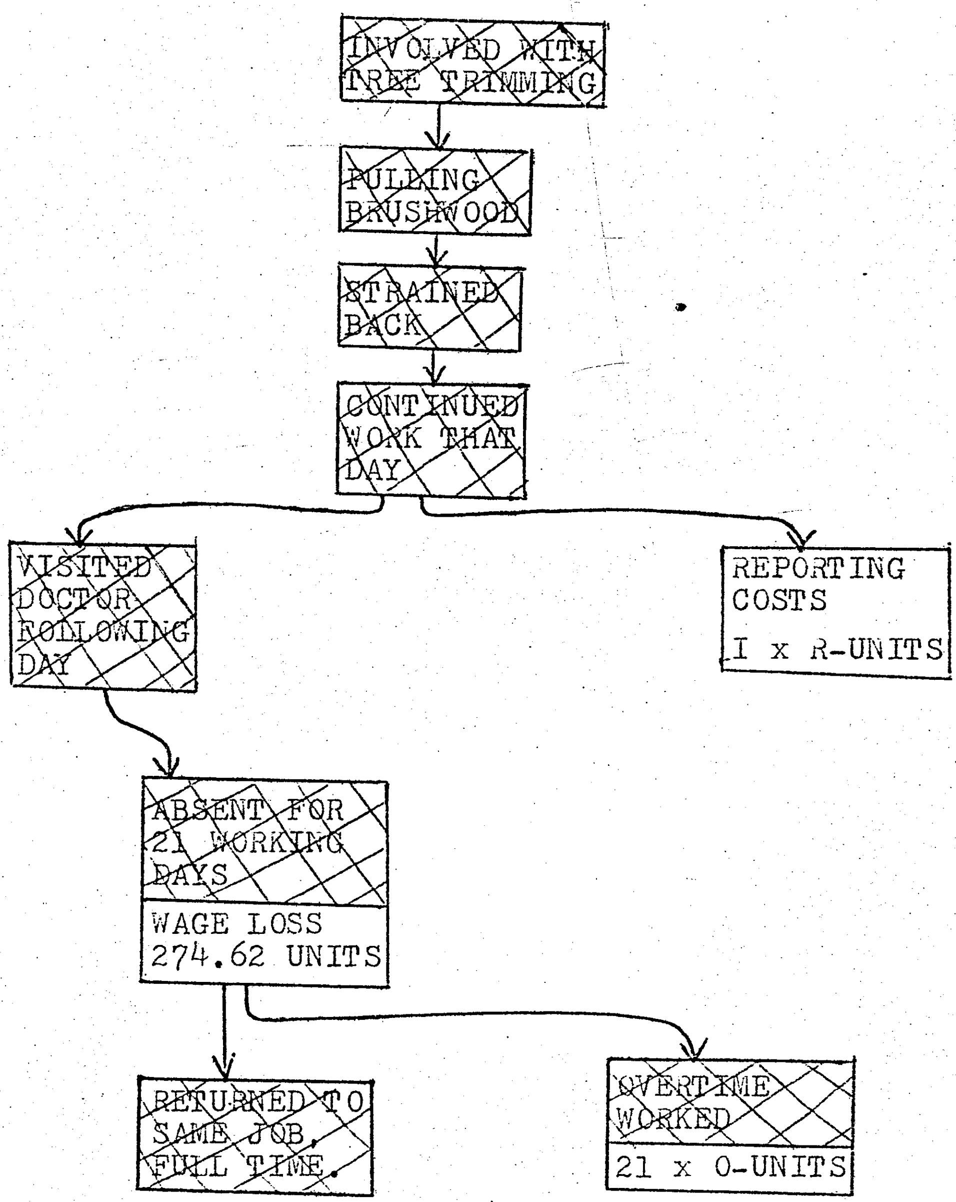
PLUS OTHER 'NON-E.S.I.' COSTS: Costs to the individual of pain & suffering
Costs to society of medical treatment & DHSS payment.

FOR KEY TO DIAGRAM AND 'UNIT' COSTING REFER TO KEY-PAGE.

Figure 39

EASTERN ELECTRICITY BOARD. NORWICH DISTRICT. CASE HISTORIES.

DRIVER 'B' ACCIDENT CLASSIFICATION: HANDLING OBJECTS



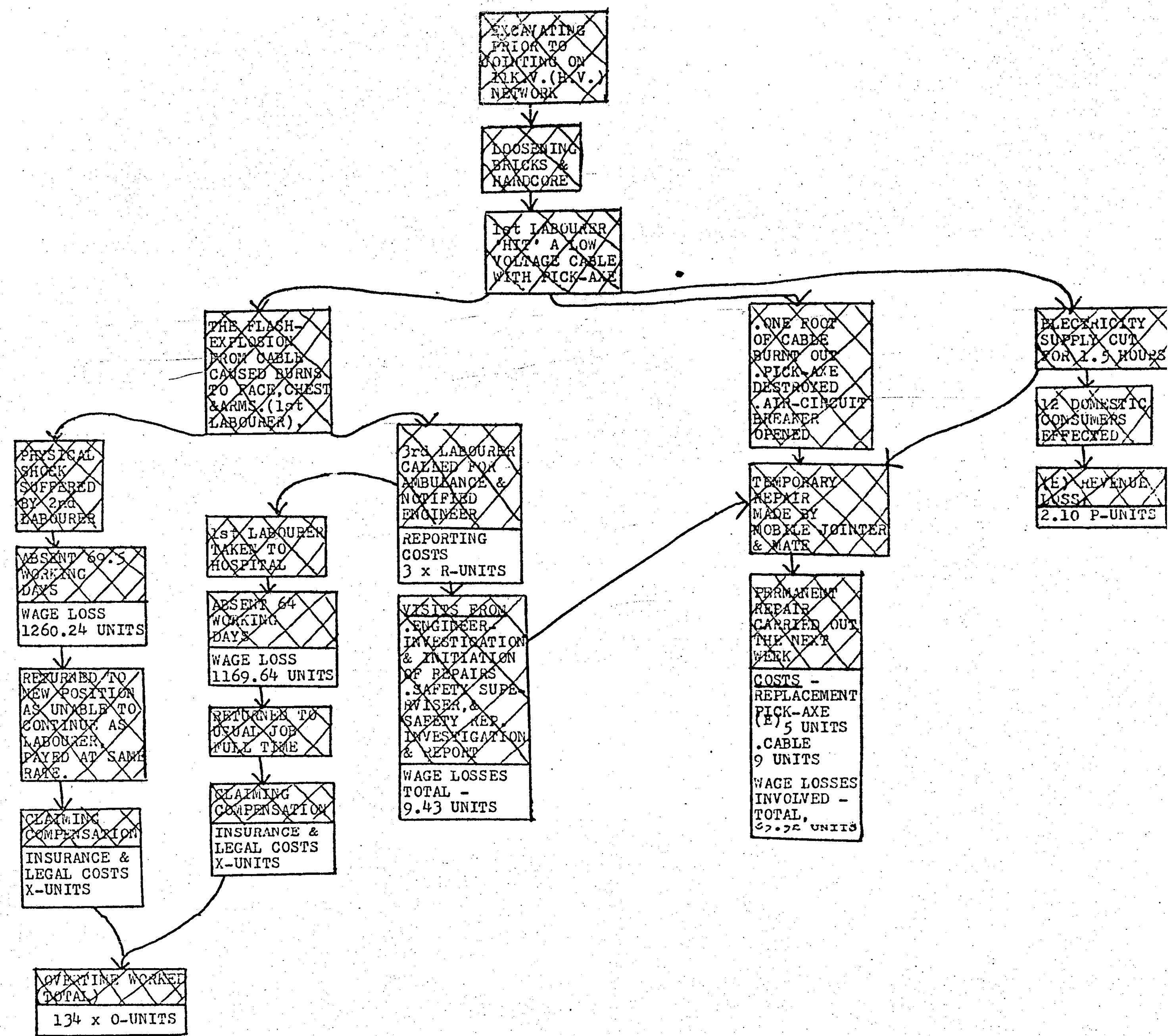
TOTAL COSTS: 274.62 UNITS, PLUS 1 xR-UNITS, PLUS 21 x O-UNITS.

PLUS OTHER 'NON-E.S.I.' COSTS: Costs to the individual of pain & sufferin
Costs to society of medical treatment &
DHSS payment.

FOR <u>KEY</u> TO DIAGRAM AND 'UNIT' COSTING REFER TO KEY-PAGE.

Figure 40

LONDON ELECTRICITY BOARD — WANDLE DISTRICT — CASE HISTORIES
2 LABOURERS — ACCIDENT CLASSIFICATION: ELECTRICITY



TOTAL COSTS: 2525.24 UNITS, PLUS 3 x R-UNITS, PLUS 134 x O-UNITS.

PLUS OTHER 'NON-E.S.I.' COSTS:
Costs to the individual of pain & suffering & suspension of normal activities.
Costs to the individual and his family of the disturbance of normal 'family-life'.
Costs to society of medical treatment involved, & DHSS payment.
Costs of inconvenience, and possible monetary loss for the consumers effected by the loss of (electricity) supply.

FOR KEY TO DIAGRAM AND 'UNIT' COSTING REFER TO KEY-PAGE.

APPENDIX NUMBER 3.

ACCIDENT REPORTING.

ACCIDENT REPORTING.

1. Statutory Obligations

1) To keep accident (record) book at work-place.

2) To report all accidents resulting in three or more days absence that occur in factories (or 'notional' factories) to the Factory Inspectorate. Reportable e.g. under the 1961 Factories Act, and the Offices, Shops and Railway Premises Act 1963.

3) To report to the Department of Energy:-
"...any accident by explosion, or fire and also any other accident of such a kind as to have caused, or to be likely to have caused, loss of life, or personal injury which has occured in any part of the Undertakers' works or their circuits, or in any connection with those works or circuits and also notice of any loss of life or personal injury occasioned by any such accident."
Regulation 38 of the Electricity Supply Regulations.

2. Electricity Council - Safety Branch Reporting

1) All accidents that result in three or more days absence, 'whenever and wherever' they occur.

2) Details of all 'lost-time' accidents, i.e. all accidents which result in 'loss of man-time' beyond the day-shift when the accident occured.

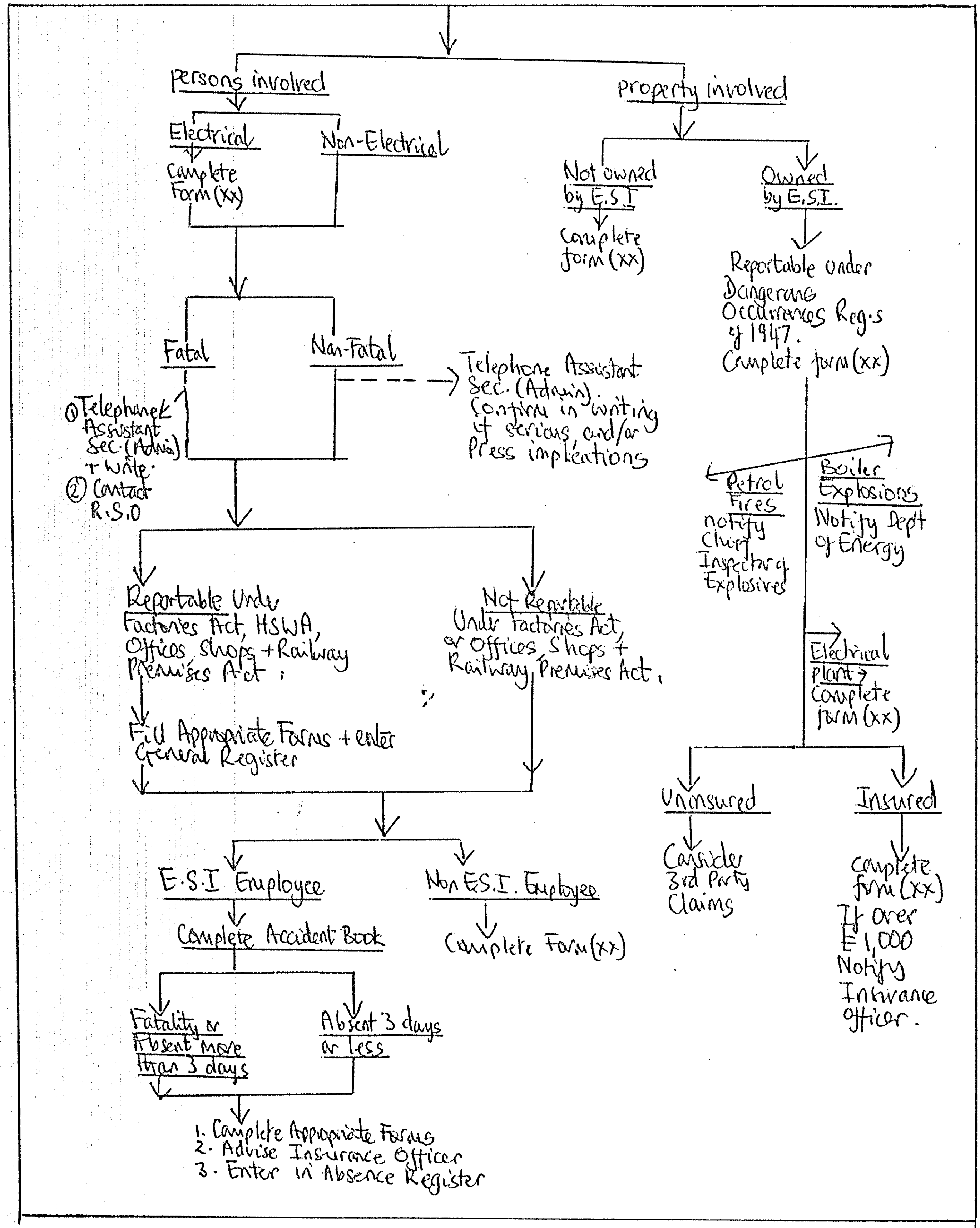


Figure 41. Flow Chart of Action and Reporting by Area Board District Units Following an Accident or Incident.

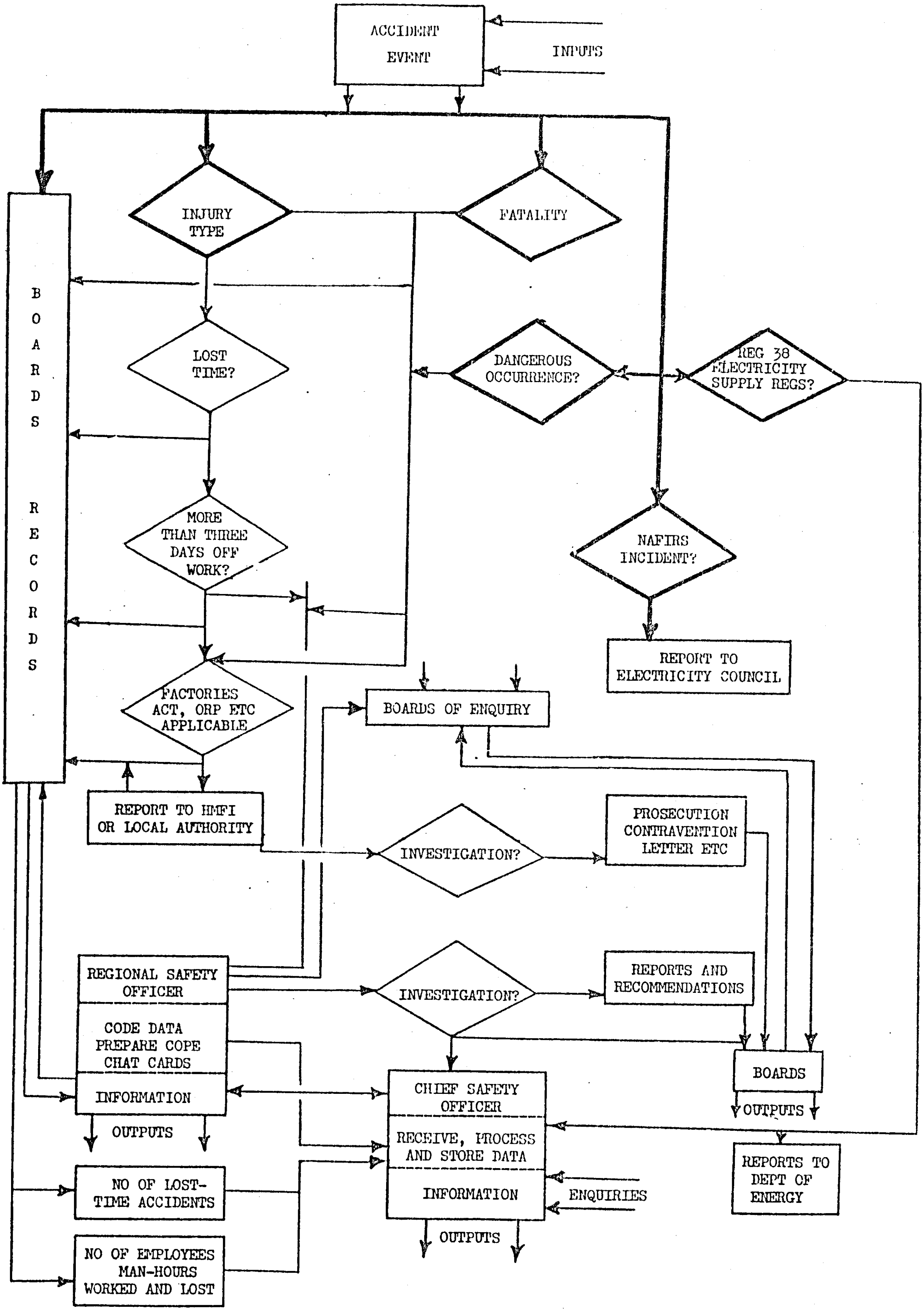


Figure 42. Accident Reporting Flow-Block Diagram - Computer System for the Whole Industry.
Source: Hooper 1976

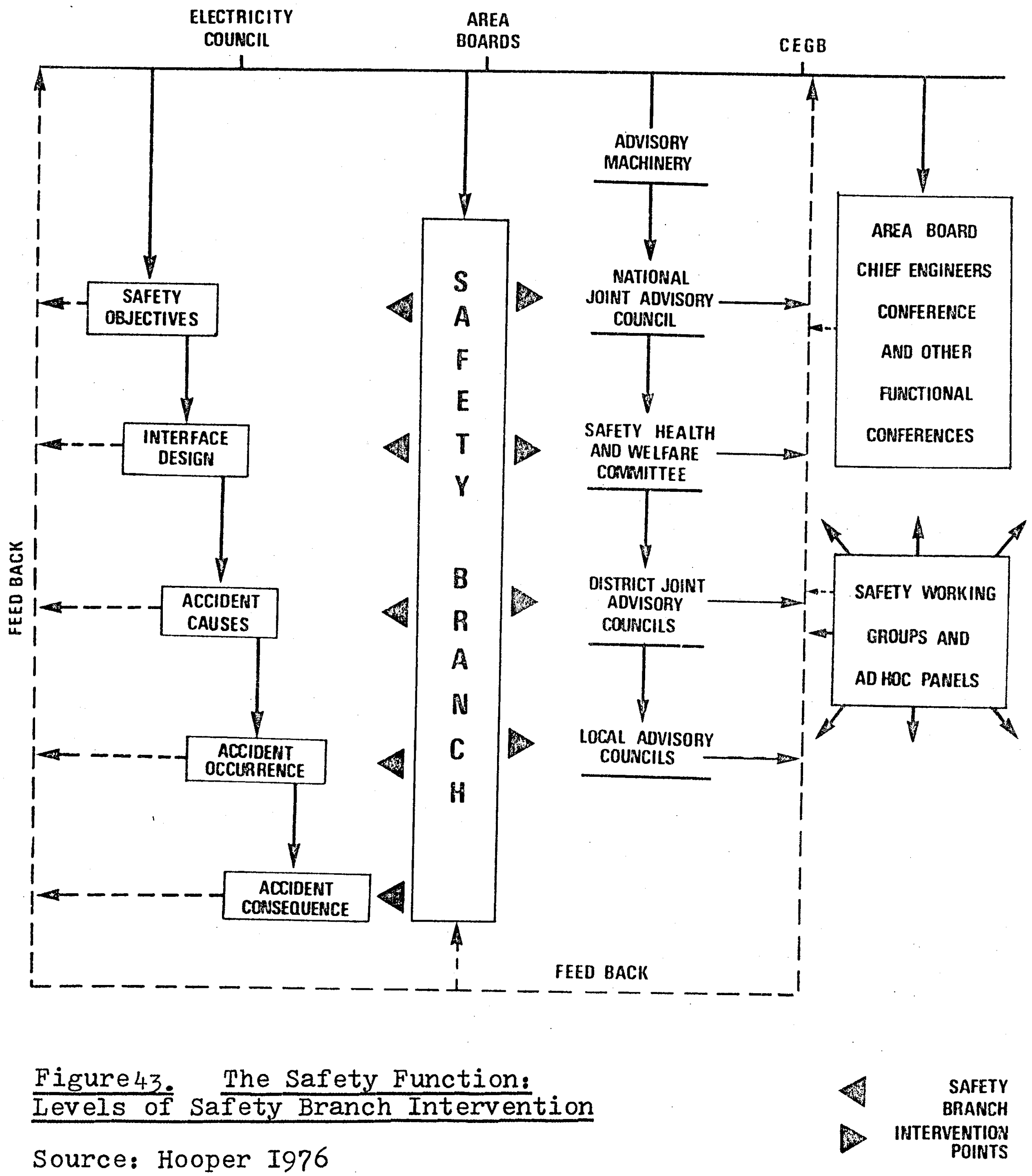


Figure 43. The Safety Function: Levels of Safety Branch Intervention

Source: Hooper 1976

APPENDIX NUMBER 4.

ELECTRICITY SUPPLY INDUSTRY ACCIDENT STATISTICS.

Period: Ist April I972 to 3Ist March I973

Area Board	Machinery (hand & power)	Transport (inc. mechanical truck)	Electricity	Explosions, Fires.	Hot Substances	Poisons & Corrosive	Persons Falling	Stepping on/striking Objects	Objects Falling	Handling Objects (by hand/hand truck)	Hand Tools	Miscellaneous	Total Accidents	Total Accidents / No.of Ind.Staff x I00
London	I0	28	32	2	7	I	49	29	9	72	I7	I5	27I	4.92
South Eastern	6	28	I6	I	5	2	49	20	8	76	24	6	24I	5.5I
Southern	I5	23	23	I	9	I	67	27	I0	98	36	27	337	5.I0
South Western	I0	9	27	2	6	-	62	I7	I4	65	28	2I	26I	5.64
Eastern	I3	27	2I	I	I0	-	57	29	I6	I0I	3I	I3	3I9	5.40
East Midlands	8	I5	I8	I	I5	I	52	28	I3	53	28	6	238	5.I0
Midlands	7	20	I7	2	I5	-	67	23	I3	86	26	8	284	5.54
South Wales	5	I4	I0	-	2	2	53	I9	2	62	I5	8	I92	6.72
Merseyside & N.Wales	I0	I5	6	I	9	-	47	25	I0	74	22	8	227	6.92
Yorkshire	9	2I	9	3	9	-	58	50	27	67	28	I2	293	6.20
North Eastern	4	I4	9	5	I0	-	47	35	35	52	I6	I5	242	7.I0
North Western	I3	I8	42	2	I3	2	77	34	3I	I03	39	I7	39I	7.I4
Totals	II0	232	230	2I	II0	9	685	336	I88	909	3I0	I56	3296	5.74

Figure 44

Period: Ist April I973 to 3Ist March I974

Area Board	Machinery (hand & power)	Transport (inc. mechanical truck)	Electricity	Explosions, Fires..	Hot Substances	Poisons & Corrosive	Persons Falling	Stepping on/striking Objects	Objects Falling	Handling Objects (by hand/h.truck)	Hand Tools	Miscellaneous	Total Accidents	Total Accidents / No.of Ind. Staff x I00
London	7	24	22	2	I0	-	62	22	I4	69	I8	I2	262	4.4I
South Eastern	I0	I6	I8	-	II	-	4I	I3	3	42	24	6	I84	4.46
Southern	I6	I7	2I	-	I2	-	70	25	8	76	37	I5	297	4.79
South Western	I4	I2	I3	-	4	I	4I	I8	5	75	I4	I6	2I3	4.62
Eastern	I6	I2	24	I	8	-	5I	I7	8	88	I9	I5	259	4.37
East Midlands	I3	I4	27	I	I2	3	39	I4	I0	56	30	3	222	4.95
Midlands	I3	I2	I7	-	II	I	48	I2	6	68	27	7	222	4.45
South Wales	7	I3	8	-	4	I	40	I5	3	38	I8	5	I52	5.38
Merseyside & N.Wales	7	II	4	I	9	-	3I	26	7	5I	I2	II	I70	5.60
Yorkshire	I6	24	I4	3	I0	-	43	30	24	77	29	I7	287	6.I8
North Eastern	5	I6	8	2	7	-	45	22	28	67	23	II	234	6.87
North Western	20	I7	3I	2	8	I	64	40	I5	93	42	I5	348	6.68
Totals	I44	I88	207	I2	I06	7	575	254	I3I	800	293	I33	2850	5.I3

Figure 45

Period: Ist April I974 to 3Ist March I975

Area Board	Machinery (hand & power)	Transport (inc. mechanical truck)	Electricity	Explosions, Fires...	Hot Substances	Poisons & Corrosive	Persons Falling	Stepping on/striking Objects	Objects Falling	Handling Objects (by hand/h.truck)	Hand Tools	Miscellaneous	Total Accidents	Total Accidents / No.of Ind. Staff x I00
London	9	I9	I3	I	I0	-	59	27	I3	45	9	II	2I6	3.90
South Eastern	II	I7	I7	2	7	-	30	II	4	48	23	II	I8I	4.6I
Southern	I8	I4	25	I	8	-	60	26	II	7I	I9	22	275	4.65
South Western	II	7	I8	-	4	-	55	2I	6	59	I6	I4	206	4.66
Eastern	I6	I8	I3	I	8	-	57	27	II	78	33	I4	276	4.60
East Midlands	I0	I4	I2	-	I0	-	44	I6	6	53	36	5	206	4.82
Midlands	I2	I4	I8	I	I5	-	53	23	I4	59	27	9	245	4.98
South Wales	6	II	8	-	I	-	39	I7	6	37	I7	6	I48	5.36
Merseyside & N.Wales	7	II	4	I	7	-	46	I7	I2	45	2I	I9	I90	6.37
Yorkshire	9	22	7	I	9	-	4I	27	24	5I	26	24	24I	5.33
North Eastern	I3	24	7	2	4	-	39	25	I0	47	II	I2	I94	5.89
North Western	I3	I0	I4	I	I6	I	52	26	20	63	35	20	27I	5.46
Totals	I35	I8I	I56	II	99	I	570	263	I37	656	273	I67	2649	4.95

Figure 46

Period: Ist April I975 to 3Ist March I976

Area Board	Machinery (hand & power)	Transport (inc. mechanical truck)	Electricity	Explosions, Fires....	Hot Substances	Poisons & Corrosives	Persons Falling	Stepping on/striking objects	Objects Falling	Handling Objects (by hand/h.Truck)	Hand Tools	Miscellaneous	Total Accidents	Total Accidents / No.of Ind. Staff x I00
London	II	2I	29	2	3	-	80	30	I3	85	I7	I4	305	5.60
South Eastern	8	I6	20	-	5	-	46	35	7	79	34	I8	268	6.73
Southern	2I	22	28	I	II	2	80	34	I6	84	25	27	35I	6.I0
South Western	I4	8	9	5	4	-	53	I9	I2	69	20	26	239	5.77
Eastern	I9	23	22	-	3	-	87	36	I0	I20	38	I9	377	6.43
East Midlands	I3	9	I9	-	9	-	35	22	I5	44	20	9	I95	4.76
Midlands	II	I2	I4	2	I3	I	67	36	I5	77	35	I3	296	6.06
South Wales	I5	7	3	-	2	I	45	I7	I3	34	I2	I5	I64	6.03
Merseyside & N.Wales	7	7	3	I	3	-	67	2I	I0	74	I9	22	234	8.03
Yorkshire	I6	22	II	-	8	-	77	33	II	55	32	20	286	6.30
North Eastern	20	I6	I6	-	7	-	52	37	I7	85	25	I0	285	8.89
North Western	8	I9	I5	2	8	3	66	36	20	I22	2I	23	343	7.II
Totals	I63	I83	I89	I3	76	7	755	356	I59	928	298	2I6	3337	6.40

Figure 47

Period: Ist April I976 to 3Ist March I977

Area Board	Machinery (hand & power)	Transport (inc. mechanical truck)	Electricity	Explosions, Fires...	Hot Substances	Poisons & Corrosives	Persons Falling	Stepping on/striking Objects	Objects Falling	Handling Objects (by hand/hand truck)	Hand Tools	Miscellaneous	Total Accidents	Total Accidents / No. of Ind. Staff x I00
London	2	26	I6	I	II	-	66	38	I5	76	26	20	297	5.60
South Eastern	I2	9	9	-	4	I	5I	28	I4	68	32	I5	243	6.27
Southern	I8	I3	I5	-	5	2	55	42	22	78	32	27	309	5.64
South Western	9	6	I0	-	7	4	39	I6	I2	63	24	I8	208	5.64
Eastern	2I	I3	I5	2	7	-	70	38	II	I45	42	22	386	6.92
East Midlands	6	I4	25	I	&	I	4I	20	II	40	I9	I7	202	5.I5
Midlands	I5	I5	I8	3	6	-	60	34	25	75	32	I5	298	5.87
South Wales	8	I6	8	-	4	-	42	23	3	28	20	I4	I66	6.34
Merseyside & N.Wales	I0	I6	4	-	6	-	52	23	I6	62	24	I4	227	7.86
Yorkshire	8	22	8	2	6	I	53	35	20	7I	34	I6	276	6.29
North Eastern	8	20	7	-	7	I	55	46	I8	62	24	23	27I	8.49
North Western	I6	24	II	2	9	-	74	28	I4	94	25	I5	3I3	6.44
Totals	I33	I94	I46	II	79	I0	658	37I	I8I	862	334	2I6	3I95	6.28

Figure 43.

RESEARCH AT LONDON ELECTRICITY BOARD

1) ANALYSIS BY STATED CAUSATION	
STATED CAUSATION	No. of ACCIDENTS
1. Transport(moved by power or not)	14
2. Electricity	13
3. Fire(not dangerous occurence)	3
4. Molten metal & hot corrosive substances	4
5. Persons falling	59
6. Falling articles	12
7. Handling goods or articles	77
8. Use of hand tools	17
9. Stepping on or striking against objects	45
10. Machinery	7
11. Miscellaneous	13
TOTAL	264

Figure 49. Summary of accidents involving more than 3 days' absence from normal employment, from April 1977 to March 1978.

1) ANALYSIS BY STATED CAUSATION	
STATED CAUSATION	
1. Transport(moved by power or not)	33
2. Electricity	24
3. Fire(not dangerous occurence)	1
4. Molten metal & hot etc.	7
5. Persons falling	58
6. Falling articles	15
7. Handling goods or articles	72
8. Use of hand tools	29
9. Stepping on or etc.	70
10. Machinery	9
11. Miscellaneous	27
TOTAL	345

Figure 50. Summary of accidents involving more than 3 days' absence from normal employment, from April 1978 to March 1979.

RESEARCH AT EASTERN ELECTRICITY BOARD

FIELD WORK CARRIED OUT AT NORWICH DISTRICT AND INCLUDED LOCAL CENTRAL SERVICE UNIT AND A METER TEST CENTRE.

1) ANALYSIS BY STATED CAUSATION	
STATED CAUSATION	No. of ACCIDENTS
1. Transport(moved by power or not)	-
2. Electricity	-
3. Fire(not dangerous occurence)	-
4. Molten metal & hot corrosive substances	-
5. Persons falling	3
6. Falling articles	2
7. Handling goods or articles	5
8. Use of hand tools	-
9. Eye accidents	-
10. Stepping on or striking against objects	1
11. Machinery	-
12. Animal attacks	-
13. Miscellaneous	5
TOTAL	16

Figure 51.a. Summary of accidents involving more than 3 days' absence from normal employment, from September 1978 to February 1979 inclusive. Six months.

2) ANALYSIS BY OCCUPATION	
Linesmen	6
Builders	1
Electricians	4
Drivers	1
Meter Mechanicians	2
Engineers	1
Storekeepers	1

Figure 51.b.

APPENDIX NUMBER 5.

THE HARD SYSTEMS METHOD.

THE HARD SYSTEMS METHOD

This method is primarily client-orientated, and aimed at assessing the relative effectiveness with which selected options satisfy a set of objectives. From this point of view systems analysis is fundamentally an attempt to define issues and alternatives for the decision maker, and then provide him with the information relevant to his choices.

Figure 52 below outlines the relationships between the systems modeller, the problem, the system and its context.

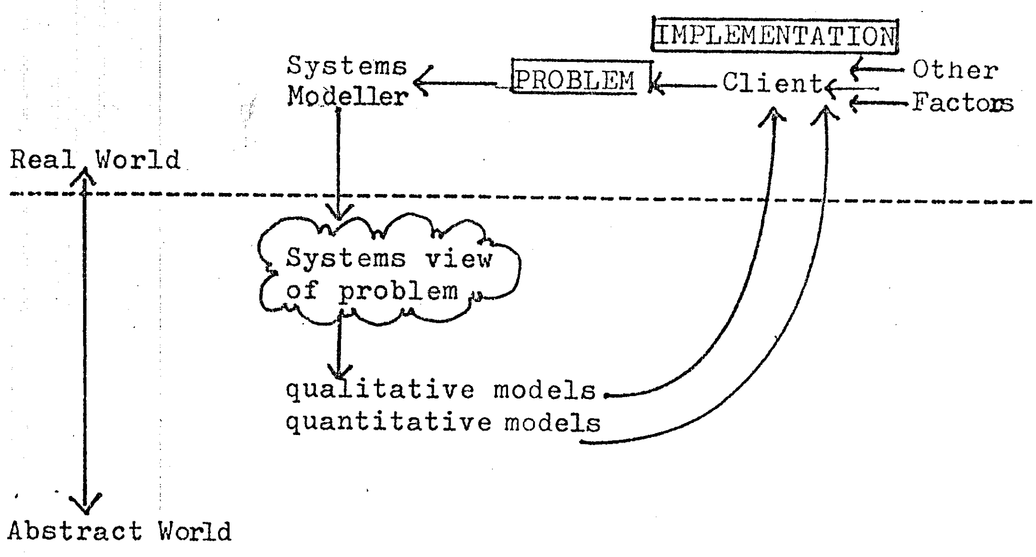


Figure 52

Prior to the core of the method there is an initial systems appreciation stage:

A) Recognition and Description of System

The initial area of study is the recognition and description of the systems of concern to the problem i.e. where the problem is to be found and systems of major influence. Systems procedures involved at this stage include:

1) Consideration and statement of interest in the problem, e.g. to describe, understand, repair and later redesign.

2) Use of the four-part definition of a system:

A system is:

(i) An assembly of parts or components connected together in an organised way.

(ii) In general, the parts are affected by being in the system and they are changed if they leave it.

(iii) The assembly of parts does something.

(iv) The particular assembly has been identified by a human being as of special interest.

3) Isolating some systems of interest; putting provisional boundaries on; and giving titles to the systems, eg. Air Traffic Control System, Earthquake Prediction System.

4) Identifying the kind of system that these systems are, eg. conflict resolution system; managed ecosystem.

5) Describing goals, flows, inputs, outputs, controls, levels, states in order to understand the structure, processes and behaviour of the system.

B) <u>Definition of Objectives and Constraints</u>

The first core stage of the Hard Systems Method is the definition of objectives and constraints.

It is the systems modeller who defines objectives from the loosely stated goals of clients.

The set of objectives to be derived must include:

1) Those associated with the problem.
2) Those of the system.
3) Those of the system's environment.

These objectives may initially be loosely defined and conflicting, but will be refined to a more pertinent reduced set.

As this method is iterative, it is usual to repeat the cycle of definition of objectives, and the recognition and description of systems several times. The major 'Phases of Iteration' are described diagrammatically later.

The definition of system objectives is the basic link between the method and the broader systems approach.

A preliminary recognition of key constraints, quantifiable and non-quantifiable, which <u>must</u> be satisfied should also be included at this stage.

C) Formulation of Measures of Effectiveness

Measures of effectiveness are measures of expected performance, which measure the degree of success or otherwise with which a proposed system option may meet its objectives, subject to constraints. Although some analysts say, "To be as objective as possible these indices should always be quantitative at least on some scale", measures for these objectives and constraints which are not readily quantifiable should be included even if only on an ordinal '+n' to '-n' scale of effectiveness (where 'n' is a whole number.). In cases where significant objectives and constraints cannot be quantified even to this degree, then qualitative judgements will still be of value and are carried forward to later stages of the method.

Measures should possess the following properties:-

1) They should reflect the objectives and constraints as far as possible.
2) They should be possible to estimate under any proposed policy option given available information.

And in the case of quantitative measures:-

3) Each measure should be a number that is unambiguously defined.

It is important to consider the different objectives of those interests, individuals and groups involved. These objectives will frequently conflict. Three different kinds of objectives may exist:

1) pure economic efficiency
2) promotion of the welfare of particular interests (at the expense of others)
3) fulfilment of desires which cannot be justified through their economic benefits.

Each of the above three types of objective can be reflected negatively in a constraint as follows:

1) economic constraints
2) institutional constraints
3) value-laden constraints.

Objectives and constraints will be of two sorts; those agreed by the actors in the situation and those attributed by the consultant. The broadest set of these is gradually refined to a smaller or reduced set - this set reflects the wide range of objectives and constraints associated with the client, the decision maker, the problem, the system, and its environment.

Selection of appropriate measures is of vital importance, as they dtermine the output of the study to a great extent. And the complexity of the frequently non-linear relationship between the measures and the values they are intended to represent should be noted. The utilities associated with each unit of efficiency or performance will not be identical.

D) Generation of Options

Although in practice the options that can be compared are often restricted, this stage is included to ensure that too narrow a view is not being taken simply by evaluating only one idea with no basis for comparison. The nature of the options may flow from the nature of the measures of effectiveness chosen.

The search for options involves two tasks:-

1) the identification of classes of solutions. This is a mind-stretching activity.
2) the examinations of a solution in a given class. This is a definition of possibilities which exhaust the most attractive variations of a particular kind of solution.

One way to tackle the problem of generating options is to examine the ways open to each of the components of the system: to look at the objectives and identify alternative ways in which these might be achieved; and then, bearing in mind any constraints on the system, to bring the avenues and alternatives together. This process should enable the suggestion of diverse policy approaches and these are then subjected to further analysis. This emphasises the need to generate as wide a range of options as possible and to reduce this only in consultation with whoever is going to take action as a result of your study - 'the client'.

One should always be aware that there is a tendancy for modellers to concentrate on developing analysis through quantitative modelling and to ignore options which do not lend themselves to analysis by known techniques. But such formal models are only <u>one</u> possible part of a systems approach.

E) <u>Evaluation</u>

Evaluation consists in associating each policy option with its expected effects in terms of the measures of effectiveness. It is here that the detailed modelling work takes place.

Evaluation takes place in two stages: the first stage consists of the quantitative analysis; the second of the non-quantitative analysis in the form of qualitative judgements. These may take the form of a ratings procedure as used in Environmental Impact Analysis.

It is important to distinguish carefully between the evaluation of the effects of each option and the subsequent selection of a particular option. The tendancy to treat evaluation and selection as the same as in methods which do not deal explicitly with systems problems, can lead to severe difficulties.

F) Selection

Selection is 'the art of balancing all the consequences.' Selection amongst options is made bt the client - the decision maker. In selection the quantitative and qualitative aspects are considered together. The results of the quantitative analysis can be reduced to the qualitative information for incorporation in a table of comparison. Selection could only be automatic in the unlikely event that all the measures of effectiveness of a system could legitimately be reduced to the same scale and added together. Only then could evaluation inherently imply the selection. The modelling work adds to the information available to the decision maker in making his choice.

G) Implementation

Implementation takes place on two levels: as conceptual implementation, and then as actual implementation.

Conceptual implementation involves considering ways of implementing the selected options against the objectives bearing in mind any constraints. In other words the cycle through all stages is repeated, this time considering implementation procedures.

Both conceptual and actual implementation involve a dialogue between the client and the modeller, with implications for change and the monitoring of the success, or otherwise, of the selected option.

The Four Phases of the Hard Systems Method

The four phases described diagrammatically below illustrate the iterative nature of the Hard Systems Method and the major paths of iteration.

The major iteration paths widen at each phase, so that:

- at phase 0 there is a tight loop focussed mainly on the objectives.

- at phase 1 it is enlarged to include analysis and design exercises at the broad policy level.

- at phase 2 the options are refined and there is detailed consideration of their implementation.

and finally:

- at phase3 the loop encompasses final selection of an option, its implementation strategy and its actual implementation.

Phase '0' Initial Understanding and Formulation.

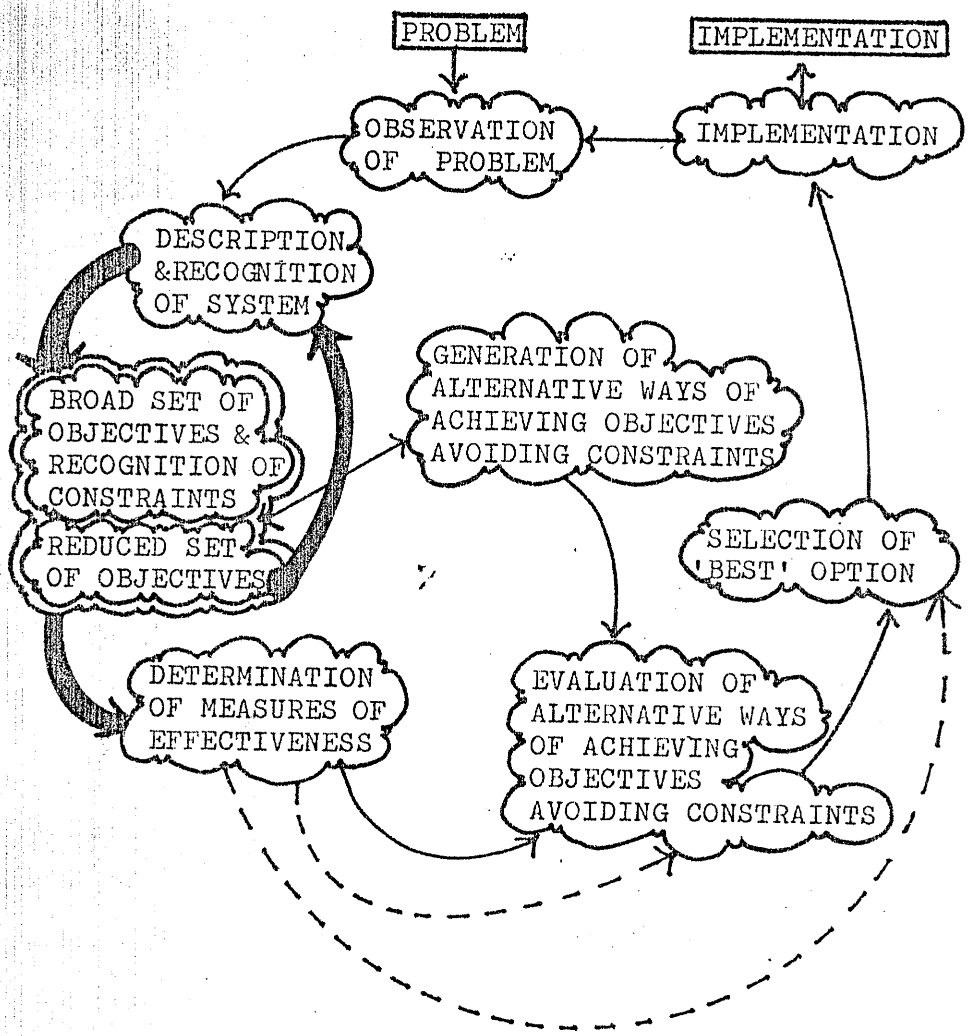
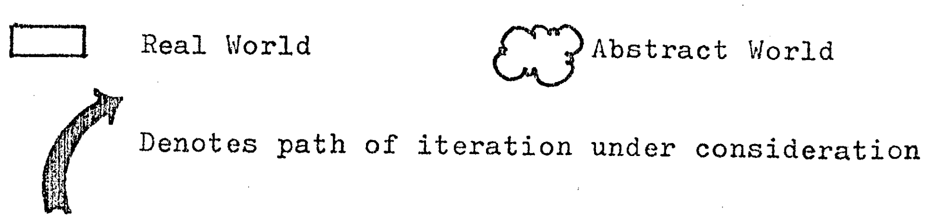


FIGURE 53.



Phase 1 Consider Broad Policy Options.

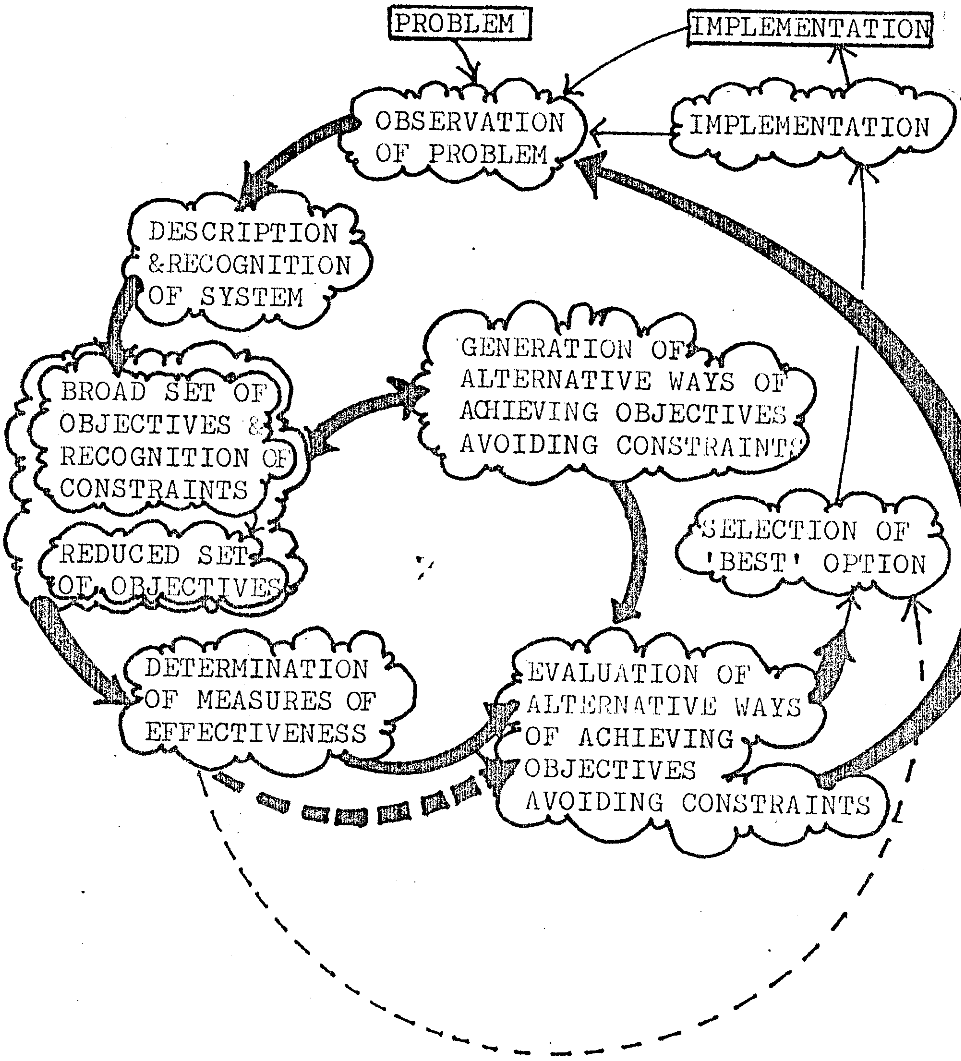


FIGURE 54

Phase 2 Considering particular options and their implementation strategy.

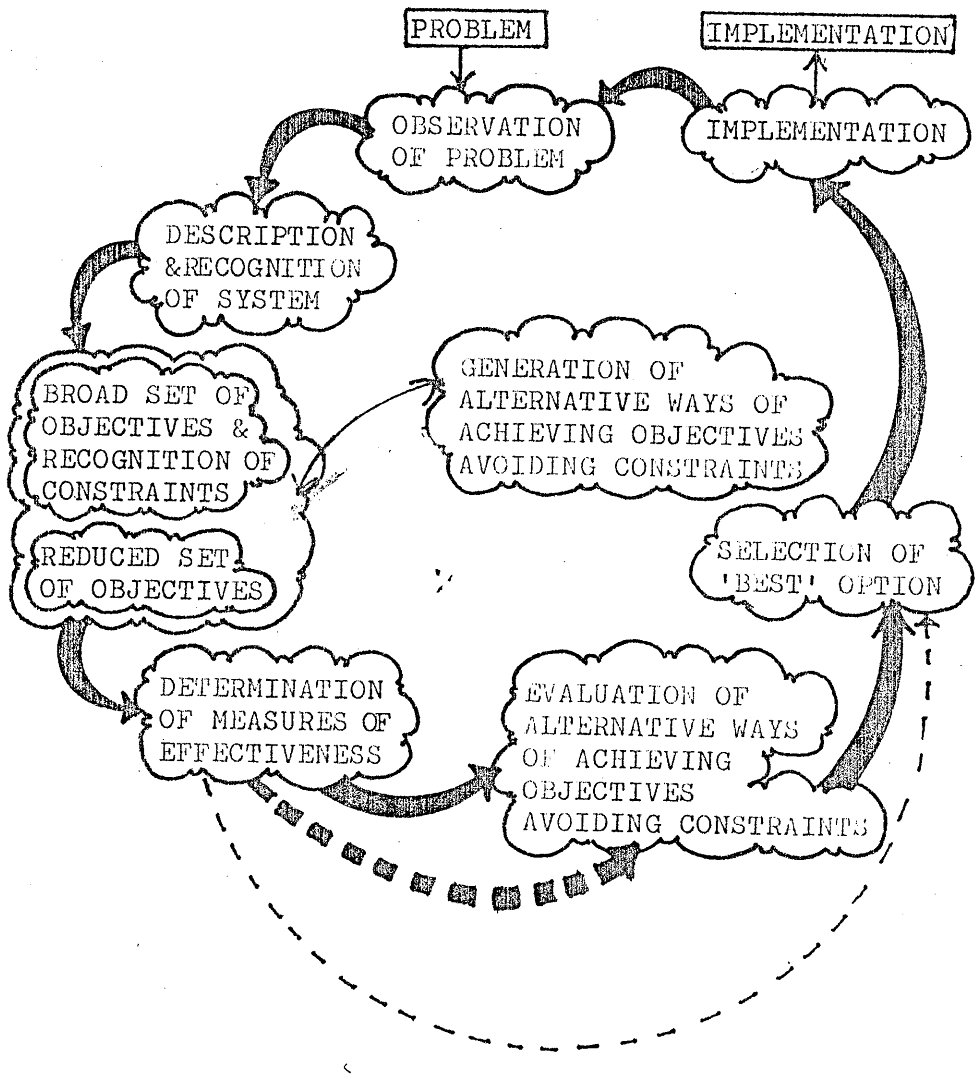


FIGURE 55

Phase 3 Selecting, finally implementing chosen options, and monitoring the system.

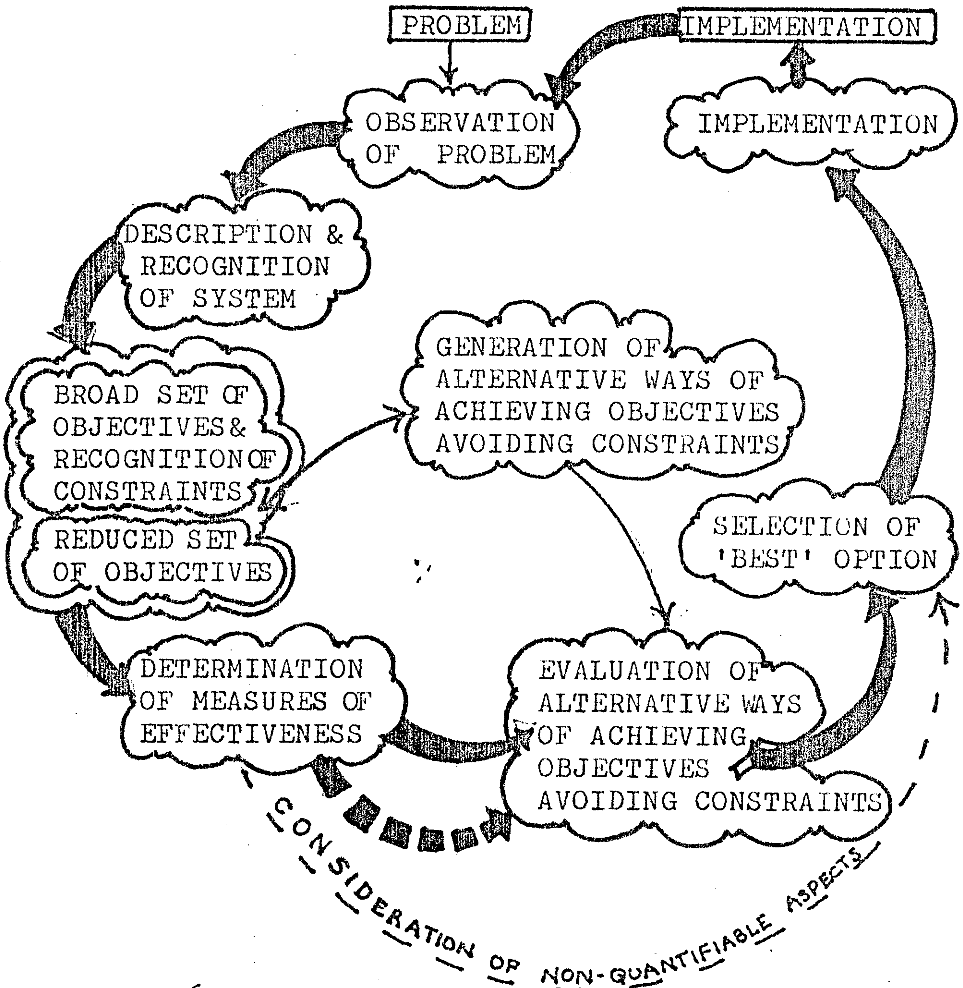


FIGURE 56

The core of this Hard Systems Method has five basic elements or stages. These are:

B) the definition of objectives and constraints

C) the formulations of measures of effectiveness

D) the generation of options

E) the evaluation of options

F) selection.

These stages are linked together into an interactive feedback loop to provide a dynamic modelling process:

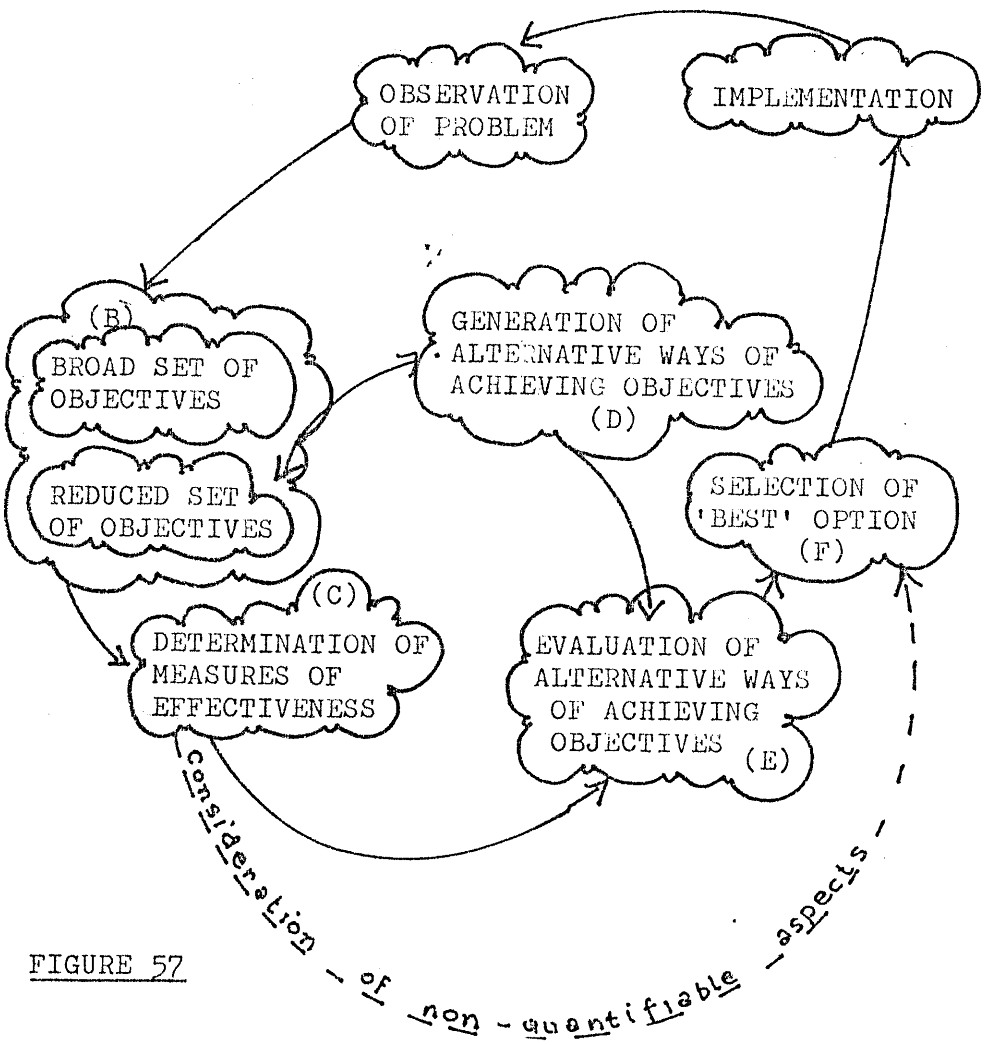


FIGURE 57

APPENDIX NUMBER 6.

THE SAFETY BRANCH OF THE ELECTRICITY SUPPLY INDUSTRY.

Appendix Number 6.

The Safety Branch.

The Electricity Supply Industry is a federated industry and the safety function is split - operating on two levels:

The Safety Branch operates as a central advisory and policy making body, with day to day safety organisation and practice taking place at the Area Board Districts under the guidance of Area Board Safety Officers, Engineering Managers and the Trade Union Safety Representatives.

The functions and the duties of the Safety Branch are outlined below and the diagrams on the following pages describe the position, organisation and levels of intervention (into the field og safety within the industry) of the Safety Branch.

The Functions and Duties of the Safety Branch.

(Source: The Annual Report of the Chief Safety Officer of the Electricity Council 1976/77)

The Branch operates from Headquaters and five outstationed offices under a Charter agreed by the Electricity Council. The duties and responsibilities of the Branch may be summarised as follows:

1) To advise the Council, the Area Boards and the CEGB on all aspects of Safety and Accident Prevention and on acceptable standards of Occupational Health (in consultation with the Industry's medical advisers) and hygiene,

excluding Nuclear hazards.

2) Generally to promote the highest standards of occupational health and safety with a view to preventing accidents and hazards to health at work by the best available means.

3) To carry out surveys of plant and premises, to investigate accidents and generally to assist the Electricity Boards at whatever level is appropriate to the circumstances, using agreed procedures.

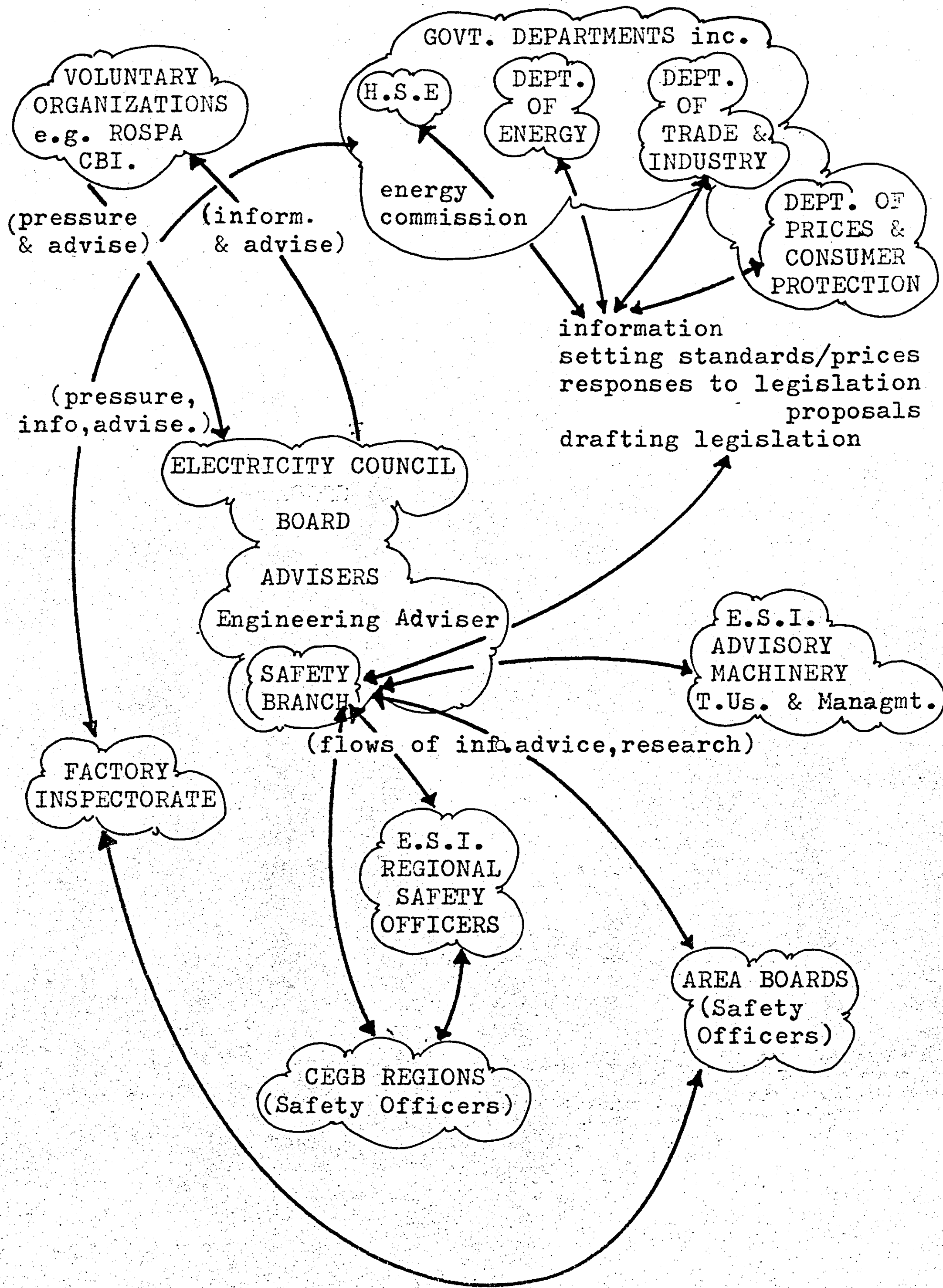


Figure 58. The Safety Branch.

KEY

↔ Flows of information, advice, pressure or research, as indicated. Direction of arrow indicates direction of flow.

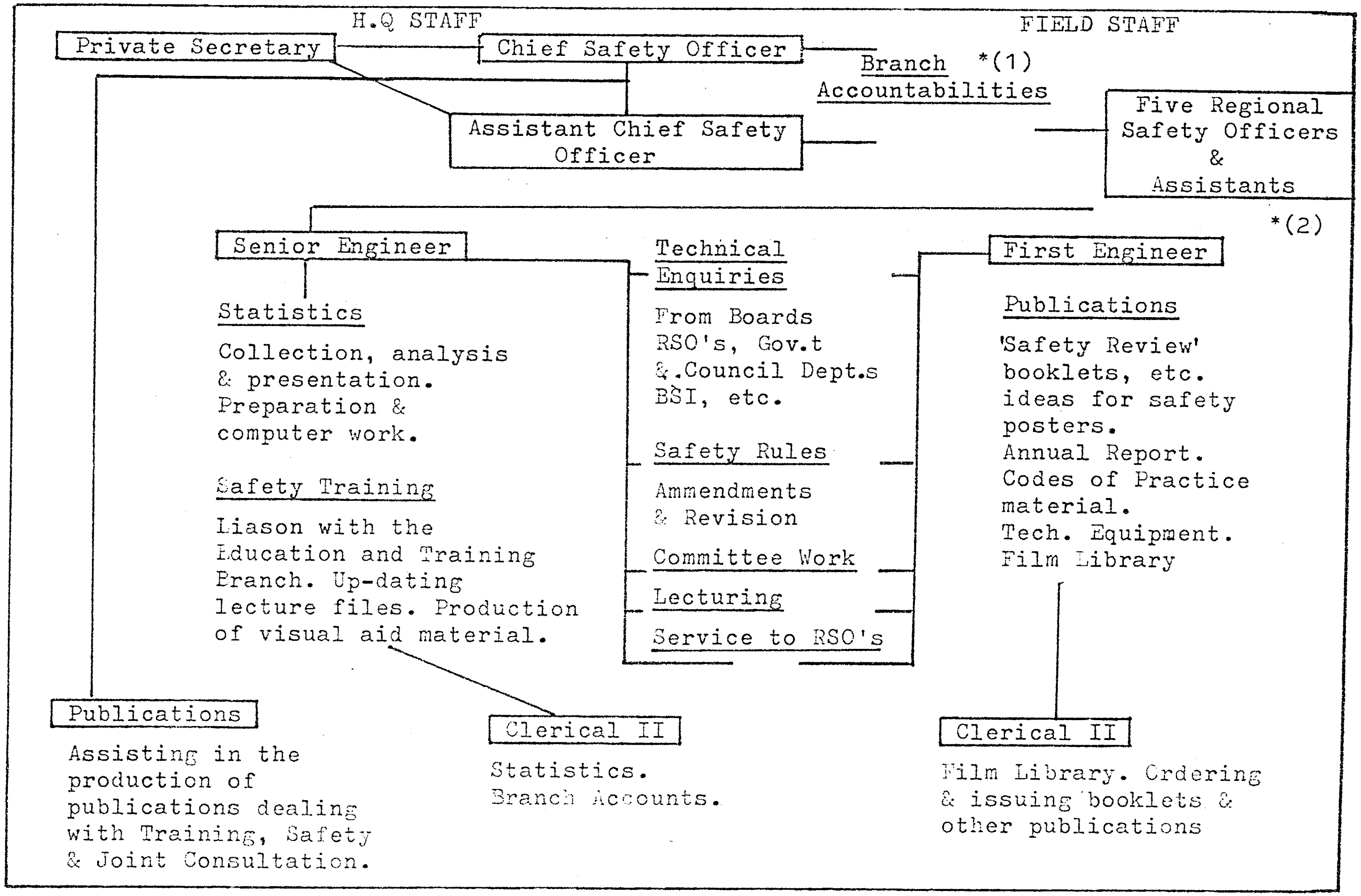


Figure 59. The Safety Branch Organisation.

*(1) Branch Accountabilities.

Advising the Electricity Council, Boards and NJAC on Safety and certain health matters.

Representing the safety interests of the E.S.I. in discussion with Government Departments.

Advising outside organisations on non-nuclear hazards arising out of the E.S.I.'s operations.

Liason with the Chief Engineer's Conference and CEGB H.Q.

Providing specialist safety and accident prevention advisory service.

*(2) Regional Safety Officers.

Advising Boards at all levels on the promotion of safety and accident prevention.

Carrying out investigations and surveys and making recommendations to management.

Liason with DJAC's.

Giving talks to various courses.

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